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THE

THEORY AND PRACTICE OF HORTICULTURE;

OR,

AN ATTEMPT TO EXPLAIN THE CHIEF OPERATIONS OF GARDENING UPON PHYSIOLOGICAL GROUNDS.

BEING THE SECOND EDITION OF THE

THEORY OF HORTICULTURE,

MUCH ENLARGED.

By JOHN LINDLEY, Ph.D. F.R.S.

Corresponding Member of the Institute,
Vice-Secretary of the Horticultural Society, Professor of Botany in University College, London,
&c. &c. &c.

"Though I am very sensible that it is from long experience chiefly that we are to expect the most certain rules of practice, yet it is withal to be remembered that the likeliest method to enable us to make the most judicious observations, and to put us upon the most probable means of improving any art, is to get the best insight we can into the nature and properties of those things which we are desirous to cultivate and improve."

Hales's *Vegetable Staticks*, i. 376.

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1855.

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TO THE

RIGHT HONOURABLE THOMAS FRANCIS KENNEDY,

Lately one of Her Majesty's Commissioners of Woods, Forests, and Land Revenues,

Who Endeavoured to Reform

A PUBLIC DEPARTMENT

IN WHICH UNSKILFUL MANAGEMENT HAS BEEN MOST DISASTROUS,

THIS EDITION

OF A WORK ON THE PRINCIPLES OF CULTIVATION,

Is Inscribed

AS A MARK OF RESPECT FOR HIGH OFFICIAL CHARACTER AND ILL-REQUITED PUBLIC SERVICES,

BY HIS FAITHFUL SERVANT,

THE AUTHOR.

PREFACE TO THE FIRST EDITION.

(1840.)

THIS book is written in the hope of providing the intelligent gardener, and the scientific amateur, correctly, with the rationalia of the more important operations of Horticulture; in the full persuasion that, if the physiological principles on which such operations, of necessity, depend, were correctly appreciated by the great mass of active-minded persons now engaged in gardening in this country, the grounds of their practice would be settled upon a more satisfactory foundation than can at present be said to exist. It is, I confess, surprising to me, that the real nature of the vital actions of plants, and of the external forces by which they are regulated, should be so frequently misapprehended even among writers upon Horticulture; and that ideas relating to such matters, so very incorrect as we frequently find them to be, should obtain among intelligent men, in the present state of what I may be permitted to call horticultural physiology. There must be a great want of sound knowledge of this subject, when we find an author, who has made himself distinguished in the history of English gardening, giving it as his opinion, "that the weak drawn state of forced Asparagus in London is occasioned by the action of the dung immediately upon its roots!"

It does not seem possible to account for this in any other way than by referring it to the want of some short guide to the horticultural application of vegetable physiology, unmixed with

other things; and so arranged that the intimate connexion of one branch of practice with another, and of the whole with a few well ascertained facts upon which everything else depends, may be distinctly perceived from a single point of view. The admirable papers of Mr. Knight are scattered through the *Horticultural Transactions;* and the writings of other physiologists are dispersed through so many different works, that the labour of finding them, when wanted, is greater than is willingly undertaken even by those who have access to ample libraries. With regard to general works on Horticulture, it is very far from my wish to say one word in disparagement of the many excellent publications upon this subject which have already appeared in this country; on the contrary, the improved state of gardening among us may be reasonably ascribed to the influence of some of these valuable works: but it must be admitted that the true principles of physiology are not, in such books, so separated from the details of routine on the one hand, or so applied to them on the other, as to be readily understood by those who want either the skill or the inclination to distinguish empirical directions from rules which are plainly founded upon the very nature of things. I must also be permitted to observe that, although results are correctly stated in such books, they are not unfrequently referred to wrong causes.

In preparing the following pages for the press, my anxious desire has been to strike out all unnecessary matter, even although it may be required to complete the physiological explanation of common facts; and to introduce little beyond that which every gardener can verify for himself. Vegetable anatomy is no doubt the foundation of all correct views of physiological action; chemistry is of the first importance, when the general functions of plants are considered in a large and general way; and electricity probably exercises an important

influence over the vital actions of all living things. But these are the refinements of science, belonging to the philosopher in his laboratory, and not to the worker in gardens; they are indispensable to the correct appreciation of physiological phenomena, but not to the application of those phenomena to the arts of life; electricity, in particular, appears to me, in the present imperfect state of our knowledge of its relation to vegetable functions, altogether incapable of forming a part of any horticultural theory.

What the gardener wants is, not a treatise upon botany, nor a series of speculations upon the possible nature of the influence on plants of all existing forces, nor an elaborate account of chemical agencies inappreciable by his senses and obscurely indicated by their visible results; but an intelligible explanation, founded upon well ascertained facts which he can judge of by his own means of observation, of the general nature of vegetable actions, and of the causes which, while they control the powers of life in plants, are themselves capable of being regulated by himself. The possession of such knowledge will necessarily teach him how to improve his methods of cultivation, and lead him to the discovery of new and better modes.

It is very true that ends of this kind are often brought about by accident, without the smallest design on the part of the gardener; and there are, doubtless, many men of uncultivated or idle minds, who think waiting upon Providence much better than any attempt to improve their condition by the exertion of their reasoning faculties. For such persons books are not written.

I hope that what has now been said will not lead any one to suppose that this sketch is offered to the reader as a complete theory of Horticulture in all its varied branches; such a work would be alike tedious to the author and the reader, and, I fear, as unprofitable; for, if a gardener, when once made acquainted

with the general principles of science, has not the skill to apply them to each particular case, it is to be feared that no disquisition, however elaborate, would enable him to do so. So far has it been from my intention to enter into subordinate details, that I have carefully avoided them, from a fear of complicating the subject, and making that obscure which in itself is sufficiently clear. All that a physiologist has really to do with Horticulture is, to explain the general nature of the vital actions of a plant, and the manner in which these are commonly applied to the arts of cultivation; if he quits this ground, he extends his limits so much that there is no longer a horizon in view. No one, indeed, could advantageously investigate the minor points of cultivation in all their branches, unless he were both a good physiologist and a practical gardener of the greatest experience, a combination of qualifications which no man has ever yet possessed, and to which I, most assuredly, have not the shadow of pretension.

In conclusion, let me, in impressing upon the minds of gardeners the importance of attending to first principles, also caution them against attempting to apply them, except in a limited manner, and by way of safe experiment, until they fully understand them. The difference between failure and success, in practice, usually depends upon slight circumstances, very easily overlooked, and not to be anticipated beforehand, even by the most skilful; their importance is often unsuspected till an experiment has failed, and may not be discovered till after many unsuccessful attempts, during which more mischief may be done by extensive failures than the result is worth when attained. No man understood this better than the late Mr. Knight, the best horticultural physiologist that the world has seen, whose experiments were conducted with a skill and knowledge which few can hope to equal. So fully was he aware of the uncertain issue of experimental investigations in Horti-

culture, that he thought it necessary, in recommending a new mode of cultivating the Pine-apple, and in objecting to methods at that time commonly in use, to express himself in the following words :—"I beg it to be understood that I condemn the machinery only which our gardeners employ, and that I admit most fully their skill in the application of that machinery to be very superior to that which I myself possess. Nor do I mean, in the slightest degree, to censure them for not having invented better machinery, for it is their duty to put in practice that which they have learned; and, having to expend the capital of others, they ought to be cautious in trying expensive experiments, of which the results must necessarily be uncertain; and, I believe, a very able and experienced gardener, after having been the inventor of the most perfect machinery, might, in very many instances, have lost both his character and his place before he had made himself sufficiently acquainted with it, and consequently become able to regulate its powers."

PREFACE TO THE SECOND EDITION.

AFTER a lapse of fifteen years the author has been called upon to prepare for the press a Second Edition of this work. In obeying the call, he gladly avails himself of the only public opportunity that he can have for thanking his foreign editors for the honour they have done him by translating the book into German,* Dutch,† and Russian.‡

He has always felt that the naked principles laid down in the First Edition were less interesting than they would have been if they had received more extensive illustration from examples and frequent reference to practical operations. He has now, therefore, greatly extended the matter, and endeavoured, whenever it appeared necessary, to support the doctrines of physiology by an appeal to facts which are or should be familiar to cultivators. In doing this he has to express his sincere gratitude to the numerous intelligent contributors to the *Gardeners' Chronicle,* who during more than fourteen years have honoured

* Theorie der Gartenkunde, &c., uebersetzt mit Anmerkungen von Ludolph Christian Treviranus. Erlangen, 1843.

Theorie der Gärtnerei, &c., aus dem Englischen übersetzt von S. G., mit einer Vorrede, Anmerkungen, und einem Anhange, versehen von einigen Freunden der Horticultur. Wien, 1842.

† Grondbeginselen der Horticultuur (Tuinkunst) naar het Engelsch van John Lindley, &c.; mit bijlagen door W. H. de Vriese. Amsterdam, 1842.

‡ Teoria Sadovodstva ili opuit iziasnenia glavneïshich proïzvodstv sadovodstva iz natshal rastitelnoi phisiologii. Edited, with various notes and additions, by J. Schychowsky. St. Petersburg, 1845.

him with their confidence, for a vast accumulation of horticultural information upon almost every point that can engage the thoughts of a gardener; it is they who have put principles to the test of experience, and who have shown how little there is of doubtful or unsound in the Theory of gardening; and he thinks it due to them to acknowledge that whatever new merit this book may possess is owing greatly to the experience gained by their friendly cooperation.

ACTON GREEN,
April, 1855.

ERRATUM.

Page 101, *for* Baroness Rolfe *read* Baroness Rolle.

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BOOK I.

THE

THEORY AND PRACTICE OF HORTICULTURE.

Horticulture is that branch of knowledge which relates to the cultivation, multiplication, and amelioration of the Vegetable Kingdom. It divides into two branches, which, although mutually dependent, are, in fact, essentially distinct: the art and the science. Under the art of horticulture is comprehended whatever concerns the mere manner of executing the operations connected with cultivation, multiplication, and amelioration; the science explains the reasons upon which practice is founded. It is to the consideration of the latter subject that the following pages are dedicated.

It must have been remarked by all intelligent observers, that in the majority of works upon horticultural subjects, the numerous directions given in any particular ramification into which the art is susceptible of being divided, are held together by no bond of union, and that there is no explanation of their connection with general principles, by which alone the soundness of this or that rule of practice may be tested; the reader is therefore usually obliged to take the excellence of one mode of cultivation, and the badness of another, upon the good faith of gardening authors, without being put into possession of any

laws by which they may be judged of beforehand. Horticulture is by these means rendered a complicated subject such as none but practised gardeners can hope to pursue successfully; and, like all empirical things, it is degraded into a code of peremptory precepts.

It will nevertheless be found, if the subject is carefully investigated, that in reality the explanations of horticultural operations are simple, and free from obscurity; provided they are not encumbered with speculations, which, however interesting in theory, are only perplexing in practice in the present state of our knowledge. When, for example, refined chemical disquisitions or minute anatomical details, or references to electrical action, are introduced, a plain subject becomes embarrassed with considerations too learned for the majority of readers of gardening works, and having little obvious application to practical purposes. Instead, therefore, of introducing points of obscure or doubtful application, or such as are merely speculative and which only tend to complicate the theory of horticulture, it seems better strictly to confine attention to the action of the simplest vital forces; for the general nature of these has been undoubtedly ascertained, and is easily understood by every class of readers. It is certain, for instance, that plants breathe, digest, and perspire; but it may be a question whether the exact nature of their respiration, digestion, and perspiration is beyond all further explanation; it is therefore better to limit our consideration to the naked fact, which is all that it imports the gardener to know, without inquiring too curiously into those phenomena. For it must always be remembered that the object of a work like the present is not to elucidate the laws of vegetable life in all their obscure details, but to teach, to those acquainted with the art of gardening, what the great principles are upon which their practice is founded.

In order to attain this end it is necessary, in the first place, to explain, however briefly, the nature of those vital actions which have a direct reference to cultivation; and further to show how those facts bear upon the routine of practice of the horticulturist, by making them explain the reason of the practical methods employed in various branches of the gardener's art.

The first part of this work therefore embraces the principal laws and facts in vegetable physiology, as deduced from the investigations of the botanist; and the second an application of those laws to practices established by the experience of the horticulturist.

If the laws comprehended in the first book are correctly explained, and the facts connected with them rightly interpreted, they must necessarily afford, in all cases, the reasons why one kind of cultivation is better than another; and all kinds of practice at variance with those laws must be bad. Seeing that, from the very nature of things, this cannot be otherwise, it follows that, by a careful consideration and due understanding of such laws, the intelligent cultivator will acquire the most certain means of improving his practice.

BOOK I.

OF THE PRINCIPAL CIRCUMSTANCES CONNECTED WITH VEGETABLE LIFE WHICH ILLUSTRATE THE OPERATIONS OF GARDENING.

A PLANT is a living body composed of an irritable, elastic, hygrometrical matter, called tissue. It is fixed to the earth by roots, and it elevates into the air a stem bearing leaves, flowers, and fruit. It has no power of shifting its place except when it is acted upon by wind or other external forces; it is therefore peculiarly susceptible of injury or benefit from the accidental circumstances that may surround it; and, having no free agency, it is above all other created beings suited to acknowledge the power of man.

In order to turn this power to account, it is necessary to study the manner of life which is peculiar to the vegetable kingdom, and to ascertain what the laws are by which the numerous actions essential to the existence of a plant are regulated. It is, moreover, requisite that the causes which modify those actions, either by increasing or diminishing their force, should be understood.

The vital actions of plants have so little apparent resemblance to those of animals, that we are unable to appreciate their nature in even the smallest degree by a reference to our own sensations, or to any knowledge we may possess of animal functions. Nevertheless, when we carefully reflect upon the phenomena of vegetation, we discover certain unquestionable analogies of a general nature, between the animal and vegetable kingdoms. And although it is necessary that plants should be

studied by themselves, as an abstract branch of investigation, without attempting to reason as to their habits from what we know of other organised beings; still it must never be forgotten that they are living things, possessed, like animals, of vitality, that mysterious force which modifies all chemical and mechanical phenomena, and which so essentially distinguishes the organic world from the brute materials of which it is composed.

In discussing this subject, it will be most convenient to divide the matter into the heads of, 1. Vital force; 2. Germination; 3. Growth by the Root; 4. Growth by the Stem; 5. Action of the Leaves; 6. Action of the Flowers; and, 7. Maturation of the Fruit. By this means the life of a plant is traced through all its principal changes, and an opportunity is afforded of introducing under one or other of these heads every point of information that can be interesting to the cultivator; who will be most likely to seek it in connection with those phenomena he is best acquainted with by their effects.

CHAPTER I.

VITAL FORCE.

MR. ANDREW KNIGHT asserted that, in the course of his numerous experiments, he had never been able to trace the existence of anything like sensation or intellect in plants, but that they always appeared to be influenced by the action of surrounding bodies, and not by any degrees of sensation and passion analogous to those of animal life. This seems to have led to the belief that they do not even possess a vital principle, but are mere chemical laboratories.

One writer ventures to call a plant a porous system—endowed with *no vitality* other than the power of forming Cytoblasts,* and arranging cellules after a definite type (*Gardner in Phil. Mag.* xxviii. 432). Even here it is admitted that some vitality exists; for the arrangement of cells, or in other words the construction of plants, each after its kind, out of cells, implies vitality of a high order, although the writer seems to have meant that a plant is little more than a bag of quaternary compounds, and to have overlooked the fact that a plant when dead is a porous system as much as when *alive*. *Nec deus intersit* is however a favourite maxim with a certain class of modern writers, although *nec absit* would appear to be more consistent with all we know of the living world.

But many discoveries have been made since the days of Knight, and a body of facts, showing the existence of high vitality, if not sensation, among plants, has been collected, with which he was wholly unacquainted. So that it is not too much to say, that the vegetable kingdom is now known to stand at least as high in the scale of life as the inferior orders of the animal kingdom.

* A Cytoblast is the vital centre round which the cell and all its contents is eventually formed.

This is shown, *a*, by the influence exercised over plants by substances such as laudanum and arsenic; *b*, by the active and visible motions of the fluid contained within their cells; *c*, by the unerring directions taken by the delicate apparatus which ensures reproduction by seed; and *d*, by the locomotive power possessed by the reproductive apparatus of the lower classes of plants.

a. It was long ago shown by Marcet, that if the common Kidney Bean, the Lilac, and other plants, were exposed to the action of such poisons as destroy animal life, they will perish not only under their influence, but in a manner analogous to what occurs among animals. If an animal is dosed with arsenic, or corrosive sublimate, or any poisonous metallic salt, it perishes by inflammation or corrosion: plants die in a similar way, their leaves turning yellow and withering, no art sufficing for their recovery. On the other hand, vegetable poisons destroy life by a species of paralysis, leaves bending, and becoming flaccid, and the whole plant rapidly falling into a state resembling stupefaction, and ending in death. Every one knows that if the inner face of the stamens of the common Berberry is touched they suddenly rise upwards and dash their anthers against the stigma; that after a time they fall back, and then become able again to present the same phenomenon. Macaire showed that when a twig of the Berberry in flower is placed in weak Prussic acid, or a solution of opium, the stamens lose their irritability, and become so flexible that they may be moved backwards and forwards without difficulty. When, however, the Berberry is placed in solutions of arsenic or corrosive sublimate, the stamens equally lose their excitability, but instead of becoming flexible, they are made stiff, hard, and brittle. Similar effects are produced upon the Sensitive Plant and other species. Here we have direct proof that the life of a plant is affected by destructive agents in the same manner as animals.

The curious effect of anæsthetic substances is the same upon plants as on animals. Dr. Marcet has shown this by means of Chloroform. "If," he says, "a drop or two of pure chloroform be placed on the point of the common petiole of a leaf of the Sensitive Plant, the petiole is soon seen to droop, and directly afterwards the leaflets collapse in succession, pair by pair, beginning with those that are situate at the extremity of each branch. A minute or two afterwards (the time varying with the irritability of the plant), most of the leaves near that on which the chloroform was placed, and situate below it on the same stem, droop one after the other, and their leaflets collapse, although not in so decided a manner as those of the leaf to which the chloroform was applied. After a certain time, which varies with the condition of

the plant, the leaves gradually open; but when touched they can no longer be irritated so as to collapse, as they do in their natural condition. They remain in this passive state, benumbed, as it were, for a considerable time, and generally it is not until some hours have elapsed that they regain their original sensibility. If, however, while in this passive state, the leaves be again touched with chloroform, they collapse as before. It is not till after several doses that they lose their sensibility entirely, or at all events until the next day; sometimes they wither completely after too many applications of the chloroform. The purer the chloroform and the greater the excitability of the plant, the greater are the effects produced."

Similar experiments with rectified ether gave results quite analogous. When the author repeated the experiment with chloroform, he found that the leaflets remained paralysed, as it were, and still unable to open after eighteen hours' rest; they seemed to be dead. This was apparently caused by excess of chloroform, a larger dose than that employed by Dr. Marcet having been used. It is thus seen that overdoses of chloroform kill plants as well as animals, though small doses are innocuous.

b. There grows commonly in ditches and stagnant water a plant called Chara, in the large cells of which a current of green globules steadily rises up one side and falls by another, presenting an appearance calling to mind the motion of an endless chain. If one of these cells is choked by a ligature, then the motion continues exactly as before in each of the two divisions so produced. The singularity of the motion, and the ease with which it may be observed, have rendered this plant a favourite object of examination by young microscopists. Those philosophers who refused to admit this to be a vital motion analogous to that of the blood, imagined that they had found an explanation in electrical action. But Dutrochet, who once held this opinion, when he attempted to establish his hypothesis upon experiment, found that the magnetic force, even when prodigious, exercises no influence whatever upon the circulation of fluid within the cells of Chara, and he was obliged to admit the presence of a vital force, of the nature of which we are wholly ignorant. Motion of an analogous nature has been now remarked within the cells of so many plants that we cannot doubt it to be a universal phenomenon. It is to be remarked that this kind of movement is wholly independent of the general motion of the sap.

c. When a grain of pollen falls upon a stigma, it protrudes a tube of extreme tenuity. The tube penetrates the stigma, much in the same manner as the root of a seed pierces the earth. Thence it proceeds unerringly to the tiny opening which it is destined to enter, passing by all obstacles, turning to the right or to the left, and now ascending, now curving back again, with the same constant certainty as would attend an act of consciousness. Nor is this all; in certain cases the

entrance of the pollen-tube into the young seed through its foramen,* is assisted by movements on the part of the seed itself, as in the common garden Thrift (Armeria) in which a horizontal strap, interposed between the pollen-tube and the foramen, is spontaneously removed in order to enable the former to enter the latter. These phenomena, varying as the structure of plants itself varies, and destined as they evidently are to ensure that great end, the propagation of species, are wholly inexplicable upon any other principle than that of high vitality; so high indeed that they are only less than voluntary actions.

d. But perhaps nothing places the presence of a powerful vital force in stronger evidence than the facts which modern botanists have discovered in connection with the propagation of the lower orders of plants. It has been known from the observations of the younger Agardh, that in fresh-water Confervæ the seeds (technically called spores) swim about with activity in the interior of the cell which generates them, that they eventually force their way through a thin part of the cell wall, and thence darting into the water move about with great activity, the lighter end downwards, and therefore contrary to the force of gravitation. These motions last for several hours. More recently it has been demonstrated that the motion is caused by delicate vibratile cilia or fringes attached to the small and narrow end of the seed (spore). This motion is stopped instantaneously by any poison, such as iodine, being allowed to mingle in the water. Discoveries of a similar nature have been made among other races of plants. Modern research has shown that in the greater part of the lowest forms of vegetable life, and probably in all, minute spiral bodies exist having the power of active locomotion in many cases. These are called ANTHEROZOIDS in consequence of the bodies or antherids which contain them being regarded as analogous to the anthers of the higher orders of plants. Sea-weeds bear both spores and antherozoids. According to M. Thuret, whose observations are not open to doubt, by placing certain sea-weeds in a damp atmosphere, the spores and antherids are freely expelled, and remain on the surface of the fronds, from which they can be readily collected and transferred to vessels containing sea-water. M. Thuret found that when put into separate vessels, the antherids placed by themselves immediately emit their antherozoids; the latter move about with great activity, even for two days successively, but on the third, begin to decompose. Spores, also, when placed in sea-water by themselves, retain their vitality for some time, not decomposing in less than a week; they even make attempts at growth, but abortions are the only consequence, and at last they perish also. It is otherwise when the spores and antherozoids are mingled in the same

* The foramen is a minute passage through the integuments of an ovule or young seed, into which the pollen-tube must enter in order to vivify the latent embryo.

vessel of sea-water. Then occurs a series of most curious phenomena. The antherozoids attack the spores, creep, as it were, over their surface, and communicate, by means of their vibratile cilia, a rotatory motion, which is sometimes very rapid. "Nothing," says M. Thuret, "is more curious than the appearance of great brown spores rolling and tumbling about in the midst of a swarm of antherozoids." The result is the fertilisation of the spore, which then begins to grow, and in ten days becomes a little cellular brown oval body, supported by a transparent rootlet. Sea-weeds are by no means the only plants in which these most remarkable phenomena have been detected. Most cryptogamic plants have now been observed to possess locomotive organs, analogous to antherozoids and bearing the same name. Liverworts, Mosses, Lycopods and Ferns themselves are supplied by nature with parts of the same description. When a Fern-seed vegetates it forms a small, thin, two-lobed green plate or scale lying horizontally on the damp surface of the ground. In this scale, called a protothall, lodge antherozoids and spores. By unknown means the former creep up to the latter, and fertilisation is accomplished. Wherever Fern-seeds have fallen, there a crop of these scaly protothalls springs up, as may be seen on the walls, or pots, or damp earth of any Fern-house. In each protothall is lodged an abundance of antherozoids and spores, the former active and capable of moving from place to place, the latter passive and stationary. Nor is there any thing in their structure which enables the observer to say whether the motions are voluntary or involuntary, so much do they resemble what is witnessed in animal life.

So far then as the important phenomena of reproduction are concerned, we have indications not only of vitality, but of such a force being present in plants in great activity.

Evidence of this kind, proving as it does beyond all doubt the presence of a vitality among plants identical with that of animals, though different in its manifestations, is greatly strengthened by the many known cases of what is called vegetable irritability.

That of the Sensitive Plant, which shrinks from the touch; of the Oscillating Saintfoin (Hedysarum gyrans) whose leaves move with as much appearance of spontaneousness as the polype; the sleep of leaves and flowers which close at night and expand in the day; the violent recoil of the column of Stylidium, or of the lip of Drakæa, when touched; the oscillation of the labellum of many Bolbophylls and Pterostyles; the snap of the traplike leaf of Dionæa which closes with great force whenever one of its six bristle-shaped springs is disturbed—phenomena familiar to the naturalist—are all intelligible

upon the supposition that they are the result of high vitality, inexplicable if referred to the operation of mere material forces.

One of the causes which have most embarrassed the progress of cultivation is not perceiving the presence among plants of this vital principle. Because plants neither walk, nor fly, nor crawl; because they are not endowed with the sense of pain or pleasure; because they neither struggle nor shriek, we are too apt to forget that they are alive, and consequently to treat them as if but rods of metal or plates of leather. Once grant that they are living beings, that they breathe although we see no mouths, that they digest although no stomachs are discoverable by common eyes, and above all things, that they feel, however low their sensations may be, and half the modes of cultivation employed by unskilful gardeners will stand conspicuous as palpable errors. Only show that plants are endowed with a life, identical in its nature with that of animals, and men must necessarily make it their first business to study the history of that life, and to master all which interferes with its healthy exercise. Such a step once taken, no cultivator would poison plants by a contaminated atmosphere, or paralyse them by an eternal footbath of cold water, or suffocate them in places where no air can reach them, or starve them by withholding the food without which they cannot exist, or cram them with incessant meals of heavy indigestible matter, which can but reduce them to the condition of an apoplectic glutton. That power which causes the bud to sprout, the leaves to form, the pollen to act, the seed to produce its embryo; which enables vegetation to breathe, and feed, and grow; which distinguishes all organised beings from the brute matter of which they consist, is the same as what gives to man the high attributes of his nature. It is VITALITY; a word which so-called philosophers in their ignorance, or presumption, may sneer at, but which in truth is the unknown force that controls the energy of matter, and directs it to special ends. It is only when cultivation is conducted with a full appreciation of this fundamental truth that Horticulture rises above the level of unreasoning custom, and acquires a solid base upon which the *rationalia* of the practices which experience seems to sanction can be permanently secured.

CHAPTER II.

GERMINATION.

THE NATURE OF A SEED.—ITS DURATION.—POWER OF GROWTH.—CAUSES OF GERMINATION.—TEMPERATURE.—LIGHT.—HUMIDITY.—CHEMICAL CHANGES.

A SEED is a living body, separating from its parent, and capable of growing into a new individual of the same species. It is a reproductive fragment, or vital point, containing within itself all the elements of life, which, however, can only be called into action by special circumstances.

But while it will with certainty become the same species as that in which it originated, it does not possess the power of reproducing any peculiarities which may have existed in its parent. For instance, the seed of a Green Gage plum will grow into a new individual of the plum species, but it will not produce the peculiar variety called the Green Gage. This latter property is confined to leaf-buds, and seems to be owing to the seed not being specially organised after the exact plan of the branch on which it grew, but merely possessing the first elements of such an organisation, together with an invariable tendency towards a particular kind of development.

Under fitting circumstances a seed grows; that is to say, the embryo which it contains swells, and bursts through its integuments; it then lengthens, first in a direction downwards, next in an upward direction, thus forming a centre or axis round which other parts are ultimately formed. No known power can overcome this tendency, on the part of the embryo, to elevate one portion in the air, and to bury the other in the earth. It is an inherent property with which nature has endowed seeds, in order to insure the young parts, when first

called into life, each finding itself in the situation most suitable to its existence; that is to say, the root in the earth, the stem in the air.

The conditions required to produce germination are, exposure to moisture, and a certain quantity of heat; in addition, it is necessary that a communication with the atmosphere should be provided, if germination is to be maintained in a healthy state. A seed, when fully ripe, contains a larger proportion of carbon than any other living part, and so long as it is thus charged with carbon, it is unable to grow. The only means it possesses of ridding itself of this principle, essential to its preservation, but forming an impediment to its development as a new plant, is by converting the carbon into carbonic acid, for which purpose a supply of oxygen is necessary. It cannot obtain oxygen in sufficient quantity from the air, for it is cut off from free communication with the air by various means, either natural, as being inclosed in a thick layer of pulp, or in a hard shell or stone; or artificial, as being buried to a considerable depth below the surface of the soil. It is from the water absorbed in germination that the seed procures the requisite supply of oxygen; fixing hydrogen, the other element of water, in its tissue: and thus it is enabled to form carbonic acid, which it parts with by its respiratory organs, until the proportion of fixed carbon is lowered to the amount suited to its growth into a plant.

It has been objected that the evidence adduced in support of this explanation is not conclusive; and that there is nothing to show that the hydrogen of decomposed water enters into new combinations or is fixed in tissue. But since no hydrogen is evolved during germination, it must necessarily be fixed or recombined after water has been decomposed. That this last phenomenon occurs is proved by the experiments of Edwards and Colin, as given in the *Comptes rendus* (vii. 922), and quoted in Lindley's *Introduction to Botany* (4th edit., II. 261 and 272).

But the formation and respiration of carbonic acid takes place most freely, though not exclusively, in darkness; if exposed to light, the seed again parts with some of its oxygen, and again fixes its carbon by the decomposition of its carbonic acid.

In addition to this, the absorption of water causes all the parts to soften and expand; many of the dry, but soluble, parts to become fluid; sap, or vegetable blood, to be formed; and a motion of fluids to be established, by means of which a communication is maintained between the more remote parts of the embryo.

Heat seems to set the vital principle in action, to expand the air contained in the numerous microscopic cavities of the seed, and to produce a distension of all the organic parts, which thus have their irritability excited, never again to be destroyed except with death. What degree of heat seeds find most conducive to their germination, probably varies in different species. Chickweed (Stellaria media) and Groundsel (Senecio vulgaris) will germinate at a temperature but little above 32° Fahr.

It has been imagined that ELECTRICAL ACTION also promotes the germination of seeds. Sir H. Davy found that seeds placed in the vicinity of the positive pole of a voltaic pile, germinated sooner than those near the negative pole; and judging from the known powers of electricity it was not unreasonable to expect, that, like light and heat, it would exert influence on the growth of vegetables. Professor Edward Solly, however, has shown, experimentally, by an extensive series of trials in the Garden of the Horticultural Society, that this is not so. Seeds of Barley, Wheat, Rye, Turnip, and Radish, were, in several different experiments, found to germinate with increased rapidity, when exposed to the influence of a feeble current of electricity of very low tension, and the plants not only came up sooner, but were more healthy than others; but, on the other hand, a number of experiments on other seeds had given quite opposite results, proving either that the germination of some seeds was retarded, whilst that of others was facilitated, by electricity; or, that the effects, observed in both cases, were merely accidental. Out of a series of fifty-five experiments on different seeds, twenty appeared in favour of electricity, ten against it, and twenty-five showed no effect whatever; and, on carefully counting the whole number of seeds up in the entire series, it was found that twelve hundred and fifty of the electrified, and twelve hundred and fifty-three of the non-electrified seeds had grown.

Germination being established, by the absorption and decomposition of water, and by the requisite elevation of temperature, all the parts enlarge, and new parts are created, at the expense

of a mucilaginous saccharine secretion which the germinating seed possesses the power of forming. With the assistance of this substance, the root, technically called the radicle, at first a mere point, or rather rounded cone, extends and pierces the earth in search of food; the young stem rises and unfolds its cotyledons, or rudimentary leaves, which, if they are exposed to light, decompose carbonic acid, fix the carbon, become green, and, by processes hereafter to be explained, when speaking of leaves, form the matter by which all the pre-existing parts are solidified. And thus a plant is born into the world; its first act having been to deprive itself of a principle (carbon) which, in superabundance, prevents its growth; but, in some other proportion, is essential to its existence.

CHAPTER III.

GROWTH BY THE ROOT.

ROOTS LENGTHEN AT THEIR POINTS ONLY.—ABSORB AT THAT PART CHIEFLY. —INCREASE IN DIAMETER LIKE STEMS.—THEIR ORIGIN.—ARE FEEDING ORGANS.—WITHOUT MUCH POWER OF SELECTING THEIR FOOD.—NATURE OF THE LATTER.—MAY BE POISONED.—ARE CONSTANTLY IN ACTION.—SOMETIMES POISON THE SOIL IN WHICH THEY GROW.—HAVE NO BUDS. —BUT MAY GENERATE THEM.

THE root, being the organ through which food is conveyed from the earth into the plant, is the part which is the soonest developed. Even in the embryo, at the earliest commencement of germination, it is the part immediately connected with the root, that first begins to move, by lengthening all its parts, and protruding itself beyond the seed-coats into the earth.

But as soon as this primitive lengthening of the root has taken place, and the upper part of the embryo, namely, the young stem, has begun to exist as a separate organ, the root changes its property, ceases to grow by a general distension of its tissue, and simply increases in length by the addition of new matter to its point. A root is therefore extended much in the same way as an icicle by the constant superposition of layer over layer to its youngest extremity, with this difference however, that an icicle is augmented by the addition of matter from without, while the root lengthens by the perpetual creation of new matter from within.

For this reason, the extreme points of the roots are exceedingly delicate, and are injured by very trifling causes; moreover, since all newly formed vegetable matter is extremely hygrometrical, they have the power of absorbing, with rapidity,

any fluid or gaseous matter that may be presented to them. On this account they are usually called *spongelets.*

In the roots of ordinary exogens, when the tissue is very young, the spongelet (Fig. I. *a*) consists of very lax tender

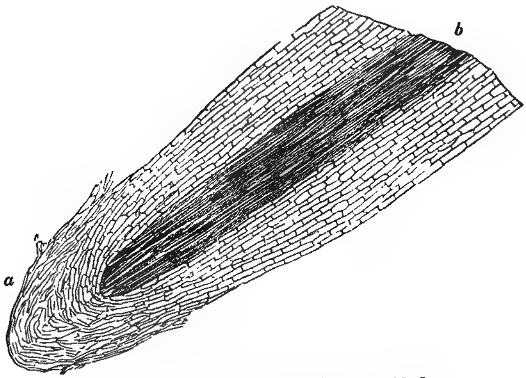


Fig. I.—Section of a Spongelet, magnified.

cellular tissue, resting upon a blunt cone of woody matter, composed principally of woody tubes, and connected with the alburnum of the stem (Fig. I. *b*); it is, therefore, placed in the most favourable position possible for communicating to the general system of circulation the fluids taken up by its highly absorbent tissue. In some roots a cap exists, called a *pileorhize,* which guards as it were the spongelet beneath it, or forms part of the spongelet.

It is the opinion of most vegetable physiologists, that the absorbing or feeding powers of roots are conducted principally at these points; and that the general surface of the root possesses little or no power of the kind. And, indeed, it seems highly probable that this is so, when we consider how thick is the bark of the root, through which fluids would have to pass before they reach the alburnum.

But although there can be no doubt that the spongelets act as absorbents with more force than any other part of the root, yet it is equally certain that the whole surface of young roots also possesses an absorbing property, only in a more limited degree. It is not until their tissue is solidified that roots

become incapable of passing fluid through their sides; and when very young and soft, there is probably but little difference between their action and that of the spongelets themselves; for it is to be remembered that the latter are not special organs, but are only the very youngest part of the root.

The absorbent power of the spongelets must be much greater than would have been supposed, if we consider that it is almost entirely through their action that the enormous waste of fluid, which takes place in plants by perspiration, is made good; and hence their importance to plants, and the danger of destroying them, become manifest.

Roots being furnished with the power of perpetually adding new living matter to their points, are thus enabled to pierce the solid earth in which they grow, to insinuate themselves between the most minute crevices, and to pass on from place to place as fast as the food in contact with them is consumed. So that plants, although not locomotive like animals, do perpetually shift their mouths in search of fresh pasturage, although their bodies remain stationary.

Many examples of this might be adduced. The following are, however, sufficient. In a Garden at Turnham Green, a Populus monilifera (Canadian Poplar) was found to have sent a root thirty feet horizontally, including its dip beneath the foundations of a wall, and then to have passed into an old well to the depth of eighteen feet, having then broken up into a mass of fibres so finely divided as to resemble yarn.

In another case, a root of the Deciduous Cypress was found by the author, eleven feet long, which had passed nearly to that length without division in search of water.

Mr. Tyso, a Florist at Wallingford, mentions the case of a Mignonette plant which had penetrated through several courses of bricks, and descended far into a wine cellar. Over the cellar, which was outside the dwelling-house, was a brick pavement, between the joints of which Mignonette seed had been sown from year to year. At the extreme end a small portion of soil was allowed, and here a plant or two grew more vigorously than the rest, though not so luxuriantly as is often found in a common border. The roots of these plants had penetrated through eighteen inches of brickwork, and some of them were hanging inside the arched roof, nourished by the damp atmosphere only. A few, more favourably situated, were attached to the end wall of the cellar, and had descended five feet five inches down the wall into the decaying sawdust of the wine-bin. Others were beautifully spread over the wall, with a

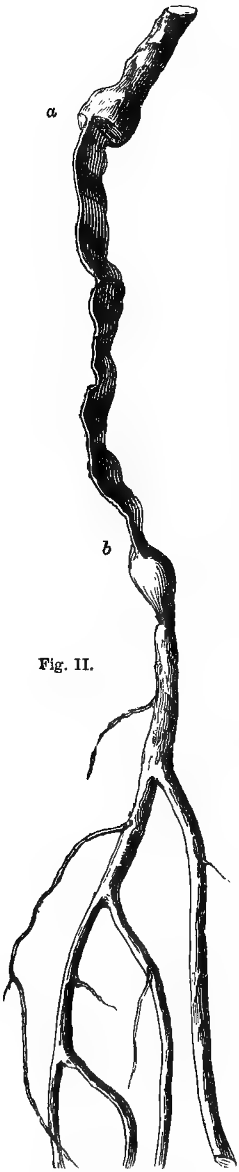


Fig. II.

thousand ramifying rootlets, bespangled with minute crystal-like damp drops, and extending over a space of five feet in width. It was difficult to trace the brittle roots that had penetrated the sawdust, but he measured some upwards of seven feet below the surface of the brickwork on which the plants were growing. It is this peculiarity which renders it so difficult to keep drains or wells in working order where roots have access. A well six feet wide has been known to be filled with roots by a common Laurel bush. Turnips and Mangel Wurzel, as well as mere weeds, have great power in this way. Patrick Neill mentions an instance of a plant of Ragwort (Senecio Jacobæa) which had insinuated the point of its roots into a drain, and had then extended them so much as to fill the drain completely for about twenty feet. And thus it is seen that it is by the point that roots extend, with an indefinite power of branching, and that the finest thread once introduced into a drain-pipe will rapidly become the origin of most extensive mischief, provided the plant is perennial. A still more remarkable case is mentioned in the *Gardeners' Chronicle* for 1849, of a line of pot-pipes from forty to fifty feet long, socketed and cemented, and thought to be perfectly closed, having become so choked by roots as to be unserviceable in fifteen years. In the side of one of the pipes there had been *one* mere chink; and through that chink some tree had insinuated the point of some root. Once inserted the point lengthened and divided, and lengthened and divided over and over again, till at last the drain-pipe was filled by an entangled mass of fibres which had pressed so firmly against each other as to form in some places a tolerably perfect mould of the cavity.

Roots lengthen, as already stated, not by extension, but by perpetual additions of very soft cellular matter to their points. That matter is in fact in the beginning mere mucilage, capable of organisation. A small portion of this mucilage finds itself in contact with a minute

cleft; conditions, the real nature of which is unknown, cause the mucilage to press against the cleft; the mucilage is introduced, it organises, solidifies, and the point of a root is established in the cleft. The point forms more mucilage in advance; that also solidifies, and a further lodgment is made; and thus the growth goes on, through all the sinuosities of the narrow passage that it traverses. In the annexed figure, the space from *a* to *b* represents the part where the root passed through the pipe, which must have been nearly two and a half inches thick; the root, there, was as thin as paper, and had followed every bend in the crack. As soon as it reached the inside of the pipe (at *b*) it swelled, acquired its usual cylindrical form, and thence proceeded to develop and branch in the manner already described. The thin connecting plate was sufficient to maintain the vitality of the roots for many years.

The only known exceptions to the rule that roots do not lengthen by a general distension of their tissue, occur in parts growing in air or water, which are non-resisting media, or in certain endogenous trees, whose roots lengthen to such a degree as to hoist the trunk up into the air, off the ground with which it at first was level.

It is not, however, merely in length that the root increases; if such were the case, all roots would be mere threads. They also augment in diameter, simultaneously with the stem, and under the influence of exactly the same causes. Neither is it by an embryo alone that roots are formed. A plant, once in a state of growth, has the power of producing roots from various parts, especially from leaves and stems.

The well-known emission of roots by the stems of the common Laurel is a phenomenon due, as it seems, to the death of the lower part of the stem, the live part of which is thus compelled to organise its descending sap in the form of roots. Vines in damp hot-houses, with their roots in a cold border, habitually exhibit the same tendency. And as a further illustration, one published by Mr. W. B. Booth may be introduced. This was the case of a Spanish Chestnut between ninety and one hundred years old, and of considerable size, cut down in 1849. With the exception of its foliage, which always had a yellowish, sickly tinge, there was scarcely anything else about it that indicated decay. Its trunk seemed perfectly sound, and the young shoots it annually made, appeared to be pretty strong and healthy. No sooner, however, had the workmen commenced cutting, than it was discovered that for ten feet high, as much as two-thirds of the bark round the trunk was dead and reduced to a mere shell. On removing this thin covering, the sap-

wood was found to have become a mass of decayed vegetable matter, through which a complete net-work of roots passed to the ground, and extended themselves for a considerable distance from the main stem. Some of these roots were about the size of an ordinary walking-stick.

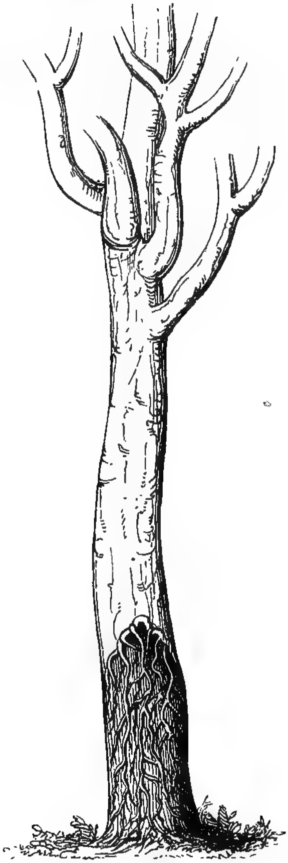


Fig. III.—Spanish Chestnut which had thrown out roots under the bark ten feet above the ground.

On tracing them to their source, they were observed to spring from the edge of the healthy portion of the tree, immediately above the part that had been injured and gone to decay; and as only a few of the larger ones reached the ground, the whole of the nourishment conveyed by the others to the tree, must have been derived from the gradual decomposition of its own sap-wood. A still more remarkable case is

mentioned in the *Gardeners' Chronicle* of 1846, p. 43, where an old Apple-tree, blown entirely out of the ground, so that all its roots were broken off, nevertheless produced roots from the hard trunk, although the accident occurred in summer when the tree was loaded with fruit.

The same observer mentions an Episcia bicolor that happened to have one of its leaves injured by an accident, which cut the midrib and a portion of the leaf on both sides of it. After a certain time the wound

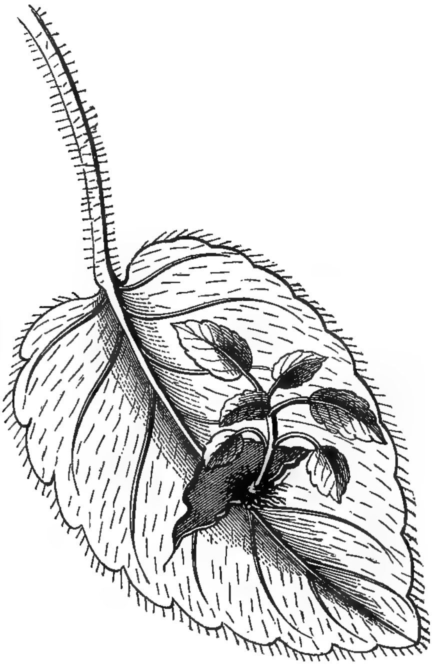


Fig. IV.—Leaf of Episcia bicolor, which had its midrib cut across by accident, and formed a young plant at the part that had been injured.

healed, the part next the base of the leaf remaining of the same thickness as before the injury, while the edge of the outer portion gradually thickened, and developed a small bud close to the midrib, from which a number of minute fibrous roots issued, and eventually a stem and leaves, as represented in the accompanying sketch. For several months the perfect plant continued to exist in this state, with no other nourishment than what the portion of the leaf on which it grew, and the air of a warm, damp, hothouse afforded it. As the plant increased in size, the old leaf gradually became exhausted, and perished altogether as soon as the young leaves gained the ascendancy and deprived it of the

scanty means that had previously supported it. Similar instances are familiar to careful observers, not the least interesting of which is that of a broken Celery leaf which had sent out roots from the lowermost of its wounded edges.

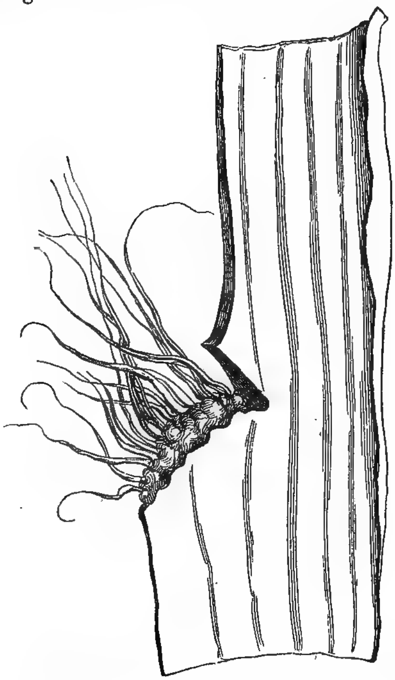


Fig. V.—Leaf of Celery producing roots from the lower edge of a wound.

The immediate cause of the formation of roots is involved in obscurity, and is one of the most important parts of vegetable physiology still to be investigated with reference to horticulture. We all know how difficult it is to cause the cuttings of some kinds of plants to produce young roots, and how rapidly they are emitted by others; it is to be supposed, that the difficulty would be diminished in all such cases, if we knew exactly under what circumstances roots are formed. Nothing, however, sufficiently certain and general to merit quotation has yet been ascertained concerning this important property, which appears to be connected with specific vitality, except the following facts, viz. that roots are most readily, if not exclusively, formed

in darkness and moderate moisture; that they are not, like branches, the development of previously formed buds, but appear fortuitously and irregularly from the woody rather than the cellular part of a plant; and that their production is in some way connected with the presence of leaves or leaf-buds, because portions of a stem having neither leaves nor leaf-buds produce roots unwillingly, if at all; and such roots perish if their appearance be not speedily followed by the formation of leaves. Thus although the first appearance of the root in the embryo plant, at the time of germination, precedes the expansion of the seed-leaves, yet the young root will not live unless the seed-leaves are enabled to act. It is certain moreover that their formation is greatly facilitated by the soil being warm, as is sufficiently proved by the readiness with which they are emitted by trees transplanted in August and September; as also by the abundance of them in warm soil, and their fewness and weak condition in soil not warmed by good drainage.

It has been remarked by a translator of this work that "the young roots of some genera live for a very considerable time without the cotyledons exercising any functions. The seeds of the Pæony, sown in January, will have formed roots in September, but the cotyledons will not be visible for four or five months later, viz., in January or February of the next year."

But, although the immediate cause of the formation of roots is unknown, the remote cause is apparently the elaboration of organisable matter by the leaves; for there can be no doubt that the development of roots is much assisted by the descending sap. When a ring of bark is removed from a branch, if the wound is wrapped in damp moss, roots will invariably push from the upper lip of the wound, while the lower will produce none; a fact so well known, that it has been one of the causes of an opinion, that roots are bundles of wood liberated from the central perpendicular system, and that the wood itself is nothing but a mass of roots formed by the leaves and buds.

The principal office of the root is to attract food from the ground. For this purpose it is furnished, as has been seen, with an extremely hygrometrical point or spongelet, which is capable of absorbing incessantly whatever matter of a suitable

kind may lie in its neighbourhood. Its force of absorption is always proportioned to the quantity of food that a plant requires: when the sap is consumed rapidly by the leaves, as in the spring, the roots are in rapid action also; and as the autumn advances, and leaves require a smaller quantity of food, the roots become more and more torpid.

The proportion borne by the root to the stem is very variable. In such plants as succulent Euphorbias, and probably in all plants whose perspiring powers are feeble, the roots are much smaller than the stem; but, in others the circle occupied by these organs must be very much greater than that of the branches. In young Oaks this is well known to be the case, but the disproportion diminishes as such plants advance in age.

There is no period of the year when the roots become altogether inactive, except when they are actually frozen. At all other times, during the winter, they are perpetually attracting food from the earth, and conveying it into the interior of the plant, where, at that season, it is stored up till it is required by the young shoots of the succeeding year. The whole tissue of a plant will therefore become distended with fluid food by the return of spring, and the degree of distension will be in proportion to the mildness and length of the previous winter. As the new shoots of spring are vigorous or feeble in proportion to the quantity of food that may be prepared for them, it follows, that the longer the period of rest from growth, the more vigorous the vegetation of a plant will become when once renewed, if that period is not excessively protracted.

A critic remarks that, of the continually-absorbing power of the roots, the simile of a wick of a candle is certainly one of the most appropriate. The wick (as well as the spongioles of the root) by its hygrometric quality continually conducts fluids to the flame, only the spongioles, being continually renewed by their constant formation, onwards, are permanent. Others doubt whether any winter absorption occurs, a fact however familiar to practical observers, and proved by such examples as those quoted at pages 50 to 52.

Powerful as the absorbing action of roots is found to be, those organs have little or no power of selecting their food; but appear, in most cases, to take up whatever is presented to them

in a sufficiently attenuated form. Their feeding property depends upon the mere hygrometrical force of their tissue, set in action in a peculiar manner by the vital principle; this force must be supposed to depend upon the action of capillary tubes, of which every part of a vegetable membrane must, of necessity, consist, although they are, in all cases, invisible to the eye, even aided by the most powerful microscopes. Whatever matter is presented to such a set of tubes will, we must suppose, be attracted through them, provided its molecules are sufficiently minute; and, as we have no reason to believe that there is, in general, any difference in the size of the molecules of either gaseous matter or fluids consisting principally of water, it will follow that one form of such matters will be absorbed by the roots of plants as readily as another. For this reason, plants are peculiarly liable to injury from the presence of deleterious substances in the earth, and it is probable that, if in many cases they reject it, it is because it does not acquire a sufficient state of tenuity; as in the case of certain coloured infusions.

But, although this appears to be a general rule, there are some exceptions of importance. If a Pea and a grain of Wheat are placed side by side in earth of the same kind, and made to grow under the same circumstances, the Wheat plant will absorb abundance of silex in solution from the earth, and the Pea will absorb little or none; whence it would seem that the Pea is unable to receive a solution of flint into its system, and that, consequently, it possesses what amounts, practically, to a power of selection. In like manner, Dr. Daubeny has proved that Pelargoniums, Barley, and the Winged Pea (Tetragonolobus) will not receive strontian; and it is mentioned by Saussure, that he could not make Polygonum Persicaria absorb, by its roots, a solution of acetate of lime, although it took up muriate of soda (common salt) freely.

It is a curious fact that the poisonous substances which are fatal to man are equally so to plants, and in nearly the same way. So that, by presenting opium or arsenic, or any metallic or alkaline poison, to its roots, a tree may be destroyed as readily as a human being.

The natural food of plants consists of carbon in the state of carbonic acid, of nitrogen, certain earths and salts, and water. The latter, if distilled, has little power, by itself, of sustaining vegetable life: but, as in nature it is universally mixed with various other substances, it conveys to the roots the nutritious matters that are required; and it furnishes, by its decomposition, a considerable supply of the oxygen consumed in the formation of carbonic acid, as well as much of the hydrogen that is assimilated by plants. It has been proved, experimentally, that plants cannot long exist upon pure water; but, if they are so circumstanced as to be able to obtain and decompose carbonic acid, they will grow in the absence of other matters. It is only, however, when the peculiar principles, whether earthy or saline, on which they naturally feed, are presented to them, that they become perfectly healthy: and especially when they have the means of obtaining nitrogen, which appears, from its great abundance in the youngest parts, to be indispensable to plants upon the first formation of their tissue.

The researches of chemists have shown that all rain-water contains ammonia, a compound of hydrogen and nitrogen, and thus the source of the nitrogen absorbed by plants was explained. But it has also been shown, especially by M. Barral, that other substances, upon which plants feed, are contained in rain-water to a much greater amount than was suspected. This observer was led, during six months of 1851, to examine minutely the water collected in the rain-gauges of the Observatory at Paris. His mode of investigation is declared by Messrs. Dumas, Boussingault, Gasparin, Regnault, and Arago, names foremost in French Science, to be free from all objection, and to bear the most severe counter trials to which they could expose it. M. Barral states, that although the quantities of the following substances varied in different months, yet the monthly average, from July to December inclusive, was as follows:—

SUBSTANCES IN A CUBIC METRE OF RAIN-WATER.

Nitrogen	8.36	grammes	=	129 grains
Nitric acid	19.09	,,	=	294 ,,
Ammonia	3.61	,,	=	55.7 ,,
Chlorine	2.27	,,	=	35 ,,
Lime	6.48	,,	=	100 ,,
Magnesia	2.12	,,	=	32.7 ,,

He did not ascertain whether all these substances are contained in rain-water collected at a distance from towns. But Dr. Bence Jones found at least nitric acid in rain-water collected in London, at Kingston in Surrey, at Melbury in Dorsetshire, and far from any town at Clonakelty in Ireland. If we assume that M. Barral's averages represent what occurs on an English acre, the quantity of such substances deposited on that extent of ground may be safely estimated as follows:—

The average depth of rain which falls in the neighbourhood of London is well ascertained to be about twenty-four inches per annum. This is at the rate of 87,120 cubic feet, or 2466 cubic metres of rain-water per acre; and this, according to the proportions per cubic metre in the preceding table, would afford annually of—

Nitrogen	45½	lbs.
Nitric acid	103	,,
Ammonia	19½	,,
Chlorine	12½	,,
Lime	35	,,
Magnesia	11	,,
Annual total per acre	227	

Of these substances the three first are of the utmost importance, on account of their entering so largely into the indispensable constituents of the food by which vegetable life is sustained. The quantity of ammonia thus ascertained to exist is about what is expected in two hundred weight of Peruvian guano; and bountiful nature gives us, moreover, nearly one hundred and fifty pounds of nitrogenous matter, equally suited to the nutrition of our crops.

It has been confidently asserted that in addition to their feeding properties, roots are the organs by which plants rid themselves of the secreted matter which is either superfluous or deleterious to them. If you place a plant of Succory in water, it will be found that the roots will, by degrees, render the water bitter, as if opium had been mixed with it; a Spurge will render it acrid; and a leguminous plant mucilaginous. And, if you poison one half of the roots of any plant, the other half will throw the poison off again from the system. Hence it has been thought to follow that, if roots are so circumstanced that they cannot constantly advance into fresh soil, they will by degrees be surrounded by their own excrementitious secretions. More correct experiments have however shown

that such results are only obtained when roots are lacerated, and that they have no greater power of excreting matter than other parts of the surface of a plant.

This theory of root excretions was sustained by Liebig, who regarded excretion as the necessary result of secretion. It is now abandoned. A correspondent of the *Gardeners' Chronicle* rightly observes, in answer to the question of what becomes of the inorganic matters which plants are constantly taking up? that in many instances, when taken up in large quantities, they are deposited in the tissues themselves so profusely as to obstruct the functions necessary to the life of the plant, and death is the consequence. Where these inorganic substances are not taken up in sufficient quantities to destroy the life of the plant, they are deposited in the tissues of the plant, either externally or internally, or both, according to its structure. Plants growing on the sea-shore, as Salsola and others, when exposed to the absorption of large quantities of sea-water, deposit in great abundance crystals of chloride of sodium in their tissues and upon their epidermis. He has examined Charas growing in pools, where the waters, from the presence of carbonic acid, hold in solution great quantities of carbonate of lime, and he has found this salt filling their large intercellular cavities, and forming a crop of beautiful crystals on their epidermis, whilst those of the same species, growing in ponds with a less quantity of carbonate of lime, have exhibited a comparative paucity of crystals. The colouring of wood, also, by introducing solutions of the metallic oxides into trees, is a good illustration of the mode in which superfluous inorganic matters are disposed of in the tissues of a plant.

As to the excretion of organic matter, there is no need to limit that function to roots, for nature assigns it to all parts of the surface, stems, leaves, flowers, and fruit, as is seen by such familiar facts as honey-dew, glandular discharges like those of the Sweet-Briar Rose, nectarial emissions, &c.

In general, roots have no buds, and are, therefore, incapable of multiplying the plant to which they belong. But it constantly happens, in some species, that they have the power of forming what are called adventitious buds; and, in such cases, they may be employed for purposes of propagation. There is no rule by which the power of a plant to generate such buds by its roots can be judged of; experiment is therefore necessary, in all cases, to determine the point.

Exceptions to the common rule are found in the Moutan Pæony, in the Plum tree, or the Pyrus (Cydonia) japonica, which may be

increased with great facility by small bits of the root being inserted in a shady border and covered with a hand-glass; but in none of them does the power reside in the same degree as in the Japan Anemone. If a root of this plant be taken from the ground after flowering, it will be found to resemble brown cord, divided into a great number of ramifications, as is represented in the accompanying cut. Upon its surface will be perceived a multitude of white conical projections, sometimes growing singly, sometimes springing up in clusters, and

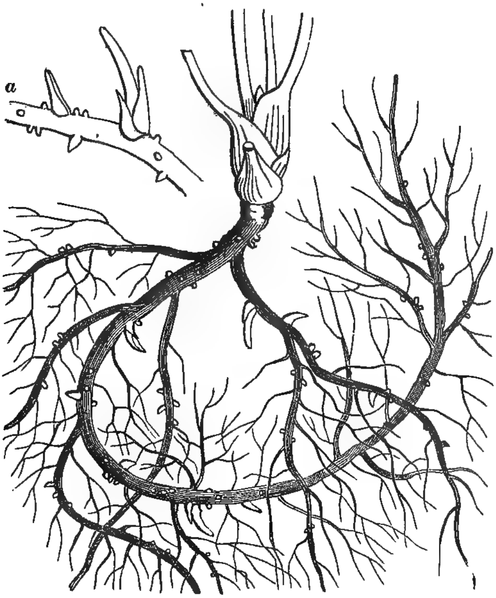


Fig. VI.—Root of Anemone japonica.

occasionally producing scales upon their sides. A magnified view of these bodies is shown at Fig. VI. *a*. They are young buds, every one of which, if cut from its parent, will grow and form a young plant in a few weeks. These buds are not confined to the main trunk of the root, but extend even towards its extremities; so that every fragment of the plant is reproductive. It is certain that vitality is stronger in the roots than in any other part of a plant. Live roots have been found in land many years after the trunks to which they belonged had been destroyed. I have myself seen live Whitethorn roots taken out of a field on the London clay where no one could recollect having seen a Whitethorn hedge. This fact was long since pointed out by Mr. Knight, who, in his experiments with fruit-trees, found continual evidence, as he has

stated, of the roots of such trees possessing far more constitutional vigour than the branches. See his *Physiological Papers*, pp. 83, 325.

The following is another instance of the kind:—On the banks of the river Derwent stood a large Hawthorn hedge, which, being undermined by the water, fell in, and left the greater part of the roots in the bank, about one or two feet below the surface; the bank still wearing away has exposed them to the air for the length of three feet or more, and they are now in every respect similar to branches, developing buds, and consequently all the appendages of the axis; they appear anatomically the same as branches, excepting the pith, of which they are destitute. Now, it appears that roots when so circumstanced perform all the functions of the stem, confirming Knight's theory, that sap can at any time generate buds, without any previously-formed rudiment, when circumstances are favourable to their production.

CHAPTER IV.

GROWTH BY THE STEM.

ORIGIN OF THE STEM.—THE GROWING POINT.—PRODUCTION OF WOOD, BARK, PITH, MEDULLARY RAYS.—PROPERTIES OF SAP-WOOD, HEART-WOOD, LIBER, RIND, ETC.—NATURE AND OFFICE OF LEAF-BUDS.—EMBRYO-BUDS.—BULBS.—CONVEYANCE OF SAP, AND ITS NATURE.

As soon as the root is fully in action, which is shortly after it has begun to lengthen, the vitality of the living point that exists at the bottom of the seed-leaves is excited, and a stem begins to be formed. At first the stem is a mere point of living matter, often invisible to the eye, but sometimes partially developed; in which latter case it is called the plumule. But, as soon as nutritive matter is conveyed into it by the nascent root, all its parts receive an impulse, which forces them into a growth upwards; what matter already exists is distended, enlarged, and solidified; new matter is rapidly generated in all directions from the vital centre, and if it were not for the current setting upwards from the root, it would possibly grow into a spherical figure. Pressed upon, however, by the surrounding earth, impelled upwards by the current of sap ascending from the root, and attracted into the air by the necessity of respiration, the young stem assumes a cylindrical form, its sides having a tendency to solidify, and its point to grow longer. This point, or plumule, or first leaf-bud, soon attracts to itself the food which the root procures from the earth, and a part of the nutritive matter which is stored up in the seed-leaves. It feeds especially upon the latter until they are exhausted, and by the time this happens it is clothed with leaves which are themselves able to feed it after the seed-leaves

have perished. In brief, the stem is a branch produced by the first leaf-bud which the embryo plant possesses.

When the stem is first called into existence, it is merely a vegetable cell, afterwards increased into a small portion of cellular tissue: an organic substance, possessing neither strength nor tenacity, and altogether unsuited to the purposes for which the stem is destined. If the stem consisted exclusively of such matter it would have neither toughness nor strength, but would be brittle like a mushroom, or like those parts of plants of which cellular tissue is the exclusive component, such for example as the club-shaped spadix of an Arum, or the soft prickles of a young Rose branch. Nature, however, from the first moment that the rudiment of a leaf appears upon the growing point of a stem, occupies herself with the formation of woody matter, consisting of tough tubes of extreme fineness, which take their rise near the leaves, and which, thence passing downwards through the cellular tissue, are incorporated with the latter, to which they give the necessary degree of strength and flexibility. In trees and shrubs, they combine intimately with each other, and so form what is properly called the wood and inner bark; in herbaceous and annual plants, they constitute a lax fibrous matter. No woody matter appears till the first leaf, or the seed-leaves, have begun to act; it always arises from near their bases; it is abundant, or the contrary, in proportion to the strength, number, and development of the leaves; and in their absence is absent also as a general rule.

The exceptional cases are those of "leafless" plants; that is to say, of plants in which leaves never advance beyond the condition of scales, and usually drop off soon after their formation. To this class belong green succulent plants like Stapelias, Cacti, and many Euphorbias. Here the bark is excessively developed, and has the colour, texture, and structure of leaves, of which it performs the functions. Such plants form true wood, but of little solidity and in small quantity compared with their bulk. It is also found that in them the wood has a lateral communication with every leaf-bud, as that of ordinary plants has with every leaf.

When woody matter is first plunged into the cellular tissue of the nascent stem, it forms a circle a little within the circum-

ference of the stem, whose interior it thus separates into two parts: namely, the bark or the superficial, and the pith or the central, portion; or, in what are called Endogens, into a superficial coating analogous to bark, and a central confused mass of wood and pith intermingled. The effect of this, in Exogens, is, to divide the interior of a perennial stem into three parts, the pith, the wood, and the bark.

Since the cellular tissue of the stem is not sensibly lengthened more in one direction than in another, and as it is that kind of organic matter, which, in stems, chiefly increases laterally, it is sometimes convenient to speak of it under the name of the *horizontal system;* and, for a similar reason, to designate the woody tubes which are plunged among it, and which increase by addition of new tubes having the same direction as themselves, as the *perpendicular system.*

Wood properly so called, and liber or inner bark, consist, in Exogens, of the perpendicular system, for the most part; while the pith and external rind or bark are chiefly formed of the horizontal system. The two latter are connected by cellular tissue, which, when it is pressed into thin plates by the woody tubes that pass through it, acquires the name of medullary rays. It is important, for the due explanation of certain phenomena connected with cultivation, to understand this point correctly, and to remember that, while the perpendicular system is distributed through the wood and bark, the horizontal system consists of pith, outer bark, and the medullary processes which connect these two in Exogens, and of irregular cellular tissue analogous to medullary rays in Endogens. So that the stem of a plant is not inaptly compared to a piece of linen, the horizontal cellular system representing the woof, and the woody system the warp.

Whenever the stem is wounded, the injury is repaired by the cellular or horizontal system, which forms granulations that eventually coalesce into masses (Fig. VII. A), within which the perpendicular system or woody matter (B) is subsequently developed. Thus the restoration of the communication between the two sides of an annular excision is effected by granulations of the upper and lower lips, and of the medullary rays, which

finally run together over the wood (Fig. VII. B), and form a coating below which new liber and alburnum may be generated.

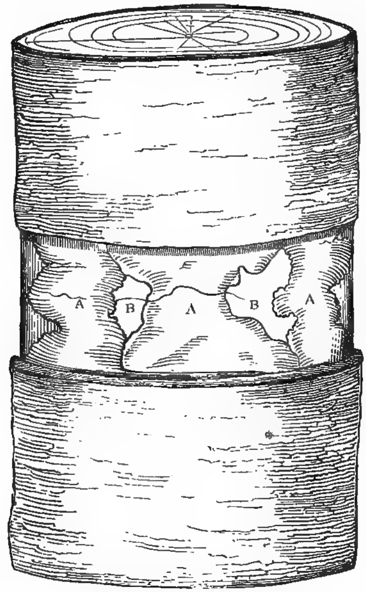


Fig. VII.—Reproduction of tissue upon a decorticated space.

In cuttings, the "callus," which forms at the end placed in the ground, is the cellular horizontal system, preparing for the reception of the perpendicular system, which is to pass downwards in the form of roots. Many plants will endure extensive lacerations of their surface, and close up such wounds with great facility. The well known fact of large inscriptions cut in trees deeper than the bark (which inscriptions were effected by removing very broad spaces of the bark and wood) being covered over in time by new bark and wood, so as to be no longer visible from the outside, sufficiently prove this. In such cases, however, the reparation of the injury takes place chiefly, if not exclusively, by the annual addition of new matter to the lips only of the wound, the effect of which is to reduce its area annually till at last the wound is closed.

"Certain it is," says Mr. Towers, "that the bark of trees, when wounded or cut in amputation of branches proceeding from the trunk, converges from all points, and not solely, as some assert, from the uppermost cross incision. The Elm-tree may furnish the best examples for investigation, some of which are to be seen in every hedge-row. In the public road leading from Waddon to Mitcham Common, there stand several large Elms in front of a gentleman's house. A wound was made in one of them fully eighteen inches long, and in the middle five or six wide, by which the bark stripped off to that extent, exposed the wood below it. The young liber came rolling forward on every side,

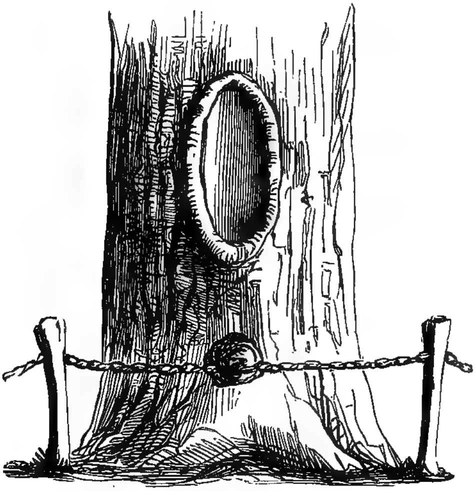


Fig. VIII.—Closing up of an oval wound.

and is now seen approaching pretty equally, though with projections of a redder colour, which mark the more recent processes. A line of posts and rails, with a chain at top, extends along the front, close to the row of trees. An abrasion or wound had been made in close contact with a part of the chain, which now is buried, and firmly fixed in the bark, by a knotty boss formed of cortical matter."

A striking instance of the power of reparation by mere superficial increase has been recorded by the Rev. M. J. Berkeley: "A vigorous Oak had been mischievously barked all round, and to such an extent as to preclude all probability of ultimate union of the severed edges. The tree, however, for a year or two seemed to suffer very little from the injury, as new tissue was thrown out from the exposed extremities of the medullary rays; and to such an extent, that had not the parties who

first injured the tree been so bent on its destruction as to cut away the newly-formed tissue, union would have speedily been effected, and the tree in all probability preserved. The growth of new tissue was not assisted by any thin strips of the inner bark still adhering to the tree, by which the descending tissue could have been conducted, but proceeded simply as indicated above, from the medullary rays."

M. Trécul has shown (*Annales des Sciences Naturelles*, Oct. 1853) that the denuded surface of the young bark (in the Elm for example) is no less capable of giving rise to a similar growth, and this whether the strips of bark separated from the stem are torn upwards or downwards, and are connected therefore with the tree above or below. New wood and bark may also be formed where there is not a single leaf, as in the case of vigorous trees cut off level with the ground. Many such instances are on record, but none more remarkable than that described by Gœppert in the Silver Fir (Abies picea, &c.) In some cases of this sort there was an inosculation with the roots of other trees; in others no such inosculation was possible.

The manner in which figures or letters carved in trees are gradually filled up affords another example of the process in question. Of this the following striking instance is illustrated in the *Gardeners' Chronicle* of 1841, by Professor Henslow:—

An Ash-tree in Coxwold, near Thirsk, was ordered to be felled and split for firewood. Upon being riven asunder, the outer part of the tree was cleft in two, like a case, leaving the inner portion of the trunk entire; and the rude inscription represented in the accompanying cut was discovered, distinctly legible, both upon the inner part of the trunk, and with the letters inverted, upon the outer casing.

There is no date to the inscription, but the period at which it was made may be ascertained, with much probability, from the following considerations. The tree is deposited in the Museum of the Hospital at Kirk Leatham, between Stockton-upon-Tees and Redcar. The porter of the Hospital, now living, can vouch for its having been there upwards of seventy years; and the tradition respecting the tree is, that it was given by Lord Falconburg, from his manor at Coxwold, to Mr. Cholmley Turner, who died on the 9th of May, 1757. It would therefore appear that the tree had been cut down nearly a hundred years. Also, by the number of rings in the wood, each indicating a year's growth, the tree appears to have been about fifty-five years old when the inscription was made, and to have subsequently grown for nearly two hundred years. The closeness of the rings near the circumference renders it highly probable that the inscription was made about three centuries ago. The height of the fragment of the tree is 5 feet 4 inches. The circumference of the inner block measures, at the upper part, 2 feet 1·5 inches; and at the lower part, 2 feet 10·75 inches: that of the outer block measures 4 feet 8·5 inches at the upper part, and 6 feet

4·5 inches at the lower part. The manner in which this inscription has been preserved and brought to light is in every respect most interesting. The letters were cut through the bark into the alburnum, or white wood below, and this very marring of the bark became the means of

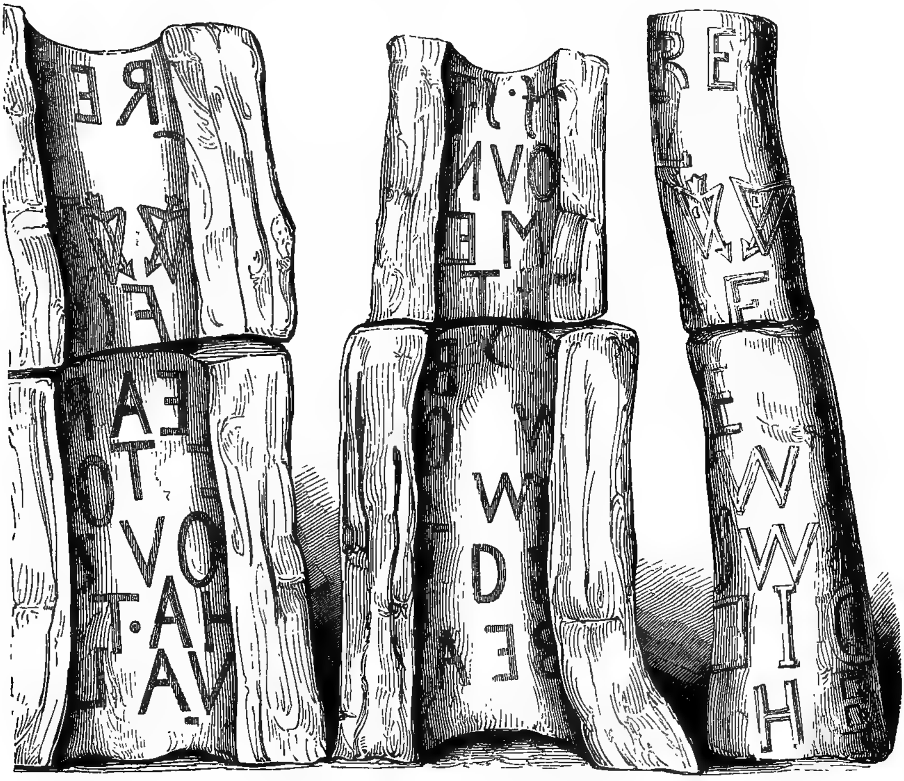


Fig. IX.—Ancient inscription covered over by new wood.

perpetuating and discovering the inscription. As the tree continued to grow, new wood would be formed between the inscription and the bark; and thus the record became buried for centuries in the heart of the tree.

In the bark of trees and shrubs, two distinct parts are found: the one external and cellular; and the other internal, resting upon the wood, and consisting of woody matter mixed with cellular. The external is the RIND or cortical integument,

the internal is the LIBER. These two parts grow independently of each other, by their inner faces; the rind belonging exclusively to the horizontal system, the liber composed of the perpendicular and horizontal systems intermixed.

In all Exogenous plants whose stems acquire an age beyond that of a very few years, the wood is distinguishable into two parts, heart-wood, and sap-wood or alburnum. The former is more or less central, and coloured brown or some other tint; the latter is external, pale yellow, and much softer. Heart-wood was originally alburnum, and altered its nature with age, in consequence of the solid matter with which all its tubes and vessels were choked up; alburnum is the youngest wood, with all its communications free and open, no solid matter having had time to accumulate within them. The reason why solid matter collects in the tubes of wood, so as gradually to choke them up, is this: the wood is the channel through which all the fluid matter of a plant, whether crude or digested, passes, in its way upwards to the leaves, or in its horizontal direction from the bark to the central parts of the stem. When sap leaves the earth and passes into the stem, it ascends by the woody matter of the finest fibres of the root: having left them, it flows into the new wood with which those fibres are connected, and passes along this until it reaches the leaves; on its return from them it descends through the liber, in part passing off horizontally towards the centre through the medullary rays. Wherever it passes it deposits a portion of its solid parts; and, consequently, that portion of the wood, namely, the oldest or the heart-wood, through which it has passed the most frequently, will have the greatest quantity of matter accumulated within it, independently of all other reasons for its hardening.

In consequence of their peculiar manner of growth, new living matter being continually formed near the circumference of the trunk, and over that which is older, Exogenous trees arrive at an old age wholly unknown in the rest of the creation. And although some of the statements on this subject may be exaggerations, yet as there is a certainty that some individual trees have lived for more than one thousand years, so it is quite possible that others may have existed for a very much

longer period. It is, however, not probable that Exogenous trees have a power of indefinite life. Upon this subject the following remarks by Professor Mohl are among the best which have been made:—

"The peculiarity of their organisation, and the unlimited power of growth of plants, offer many difficulties to the definition of the duration of plants, and have given rise to many incorrect theories. Every individual cell, and every individual organ, has a determinate end to its life; but the entire plant has not, since the individual shoots run through their periods of development quite independently, and only share in the weakness of age of the older organs when these are no longer able to convey to the young shoots the needful amount of nourishment, in which case the latter do not die from deficiency of vital energy, but are starved. It therefore depends wholly upon the mode of growth of a plant whether this occurs or not. When a plant possesses a thallus spreading horizontally by the growth of its circumference, it can annually extend itself into a larger circle, after the old parts in the centre have been long decayed, as is seen in old specimens of crustaceous Lichens, in the fairy rings caused by Fungi, &c. In like manner when a higher plant has a creeping stem, and possesses the power of sending out lateral roots near the vegetating points, and in this way conveys nourishment directly to the young terminal shoots, the latter are wholly independent of the death of the older parts of the stem and of the primary roots, and there exists no internal cause for death in such a plant. It is truly a different plant every new year and vegetates in a new place, but there is no definite boundary between it and its predecessors; such a plant is like a wave rolling over the surface of a sheet of water; it is every moment another and yet always the same. Thousands of inconspicuous plants, of Mosses, Grasses, Rushes, &c., have vegetated in this manner upon peat bogs and similar localities perhaps for thousands of years. Plants with upright stems are placed in much more unfavourable circumstances. It has been declared of these also, and particularly of the Dicotyledonous trees (De Candolle, *Physiologie Végétale*, ii. 984), that they have no internal cause for death, but I believe incorrectly. Examples of very old trees, such as De Candolle collected (*e. g.*, Taxus 3000, Adansonia 5000, Taxodium 6000 years old, &c.), only prove, naturally, that death occurs at a very late period in many plants placed in favourable circumstances, but not that it does not necessarily happen. To me there appears to exist in all trees, whether they belong to the Dicotyledons (Exogens), or, like the Palms, to the Monocotyledons (Endogens), an internal cause which must produce death in time—namely, the increasing difficulty of conveying the necessary quantity of nourishment to the vegetating point, resulting from the elongation of the trunk from year to year. Even when the force which carries the sap up, suffices to raise it to two hundred feet or more (many Palms, as Ceroxylon andicola, Areca

oleracea, attain a height of one hundred and fifty to one hundred and eighty feet; some Coniferæ, *e. g.*, Pinus Lamberti, Abies Douglasi, of more than two hundred feet), yet a maximum is reached there, and the terminal shoot is less perfectly nourished every succeeding year, becomes stunted more and more, and the tree at length dies. If we are surprised at the intensity of the vegetative force of individual plants, in consequence of which it re-appears with new, unweakened energy in every bud, so must we marvel at the force committed to so simple an organ as a cell is, if we reflect what an influence it exerts upon the total economy of nature, as one of the grandest of phenomena. The plant lives almost solely upon inorganic substances; its cells are chemical laboratories in which these are combined into organic compounds. The plant prepares in this way not only the nutriment required for its own development, but also the food on which the entire animal kingdom depends. But plants not only nourish animals, they maintain the air in a fit state for their respiration, since their breathing process removes carbonic acid from the atmosphere and replaces it by oxygen gas. In all these functions the plant is thoroughly dependent upon the outer world; its food is brought to it without its own cooperation by water and air; its respiration takes place without activity of its own, through a penetration of its substance by gases with which it is in contact, in consequence of a physical law; not even does its internal circulation of juices depend on a mechanical activity of a circulating system; thus every necessity for motion is removed. It is true we here and there meet with movements in this or that organ, but these, occurring isolated in the vegetable kingdom, are also altogether of subordinate kind in the individual plant."

The stem of a plant consists, then, of the following parts, viz.: 1. *Wood*, the oldest of which is heart-wood, and the newest alburnum; this is the substance through which sap ascends: 2. *Bark*, the external coating, down the liber or inner face of which sap descends: 3. *Pith*, a central portion of the horizontal system: and, 4. *Medullary Rays*, serving to connect the bark with the pith, to hold all the parts together, and to maintain a communication between the centre and the circumference of a stem. The stems of all plants have these four parts more or less evident. They are most visible in European trees or shrubs, in any of which they can be distinctly observed; they are least apparent in annual and herbaceous plants, because their lines of separation are not defined, all the four parts adhering to each other so firmly as to render it difficult to

separate them; and in Endogens they are all mixed together, in consequence of the manner of growth of those plants not requiring the same kind of arrangement of parts as is indispensable in Exogens.* This will be sufficiently illustrated by the comparison of the stems of an Oak, a Cabbage, and an Asparagus.

Tubers, the root-stock of the Iris and Ginger, what are called the roots (corms) of the Colchicum and Crocus, are all so many different forms of stem.

It is the property of a stem, during its growth, to form upon its surface, at irregularly increasing or diminishing distances, minute vital points of the same nature as that in which the stem itself originated. Each of those points becomes, or may become, a leaf-bud, capable of forming other stems or branches like that on which it appeared; and each is protected and nourished by a leaf which springs from the bark immediately below the bud. Such leaf-buds are the parts that enable a stem, when reduced to the state of a cutting, to produce a new individual like itself; and, without them, propagation by portions of the stem is, under ordinary circumstances, impossible.

Leaf-buds are capable, under fitting circumstances, of growing when separated from their mother branch, whether they are planted in the earth, or inserted below the bark of a kindred species. In the former case, they emit roots into the soil; in the latter they produce wood, which adheres to the

* As this work excludes everything botanical that does not directly bear upon horticultural purposes, I have not explained the difference between Exogens and Endogens; wishing the reader to refer for information upon such points to works upon pure botany. Nevertheless as these words are of frequent occurrence, I may as well state that they denominate the two greatest classes in the vegetable kingdom, to one or other of which almost all the flowering plants of common occurrence are referable, and that they derive their names from the peculiarity of their manner of growth. EXOGENS (literally, *outside-growers*) are plants whose woody matter is augmented annually by external additions below the liber; and, consequently, they are continually enclosing within their centre the woody substances formed in previous years; to such plants, a lateral communication between the centre and the circumference, by means of medullary rays, seems necessary. ENDOGENS (literally, *inside-growers*) are plants whose woody matter is augmented annually by internal additions to their centre; and, consequently, they are continually pushing to their circumference the woody substance formed in previous years.

wood on which they may be placed. Under ordinary circumstances, leaf-buds will not form anywhere except at the axils * of leaves; but occasionally they appear from other parts, such as the root (see page 31), the spaces of the stem which lie between the leaves (the internodes), and even from the leaves themselves (see page 23). In all such cases, they are termed *adventitious*, because of the uncertainty of their appearance. A very remarkable state of them is the *embryo-bud*, a name applied to the *knaurs*, *knurs*, nodules, or hard concretions, found in the bark of various trees, which seem to have, occasionally, the power of propagating the individual, notwithstanding their deformed and indurated state.

The connection between the formation of timber and the action of buds will be considered hereafter, when speaking of the wood-forming power of leaves, which are organs resulting wholly from the development of buds.

Bulbs are buds of a particular kind, larger than common, containing an unusual quantity of organizable matter, and separable, spontaneously, from the part which bears them.

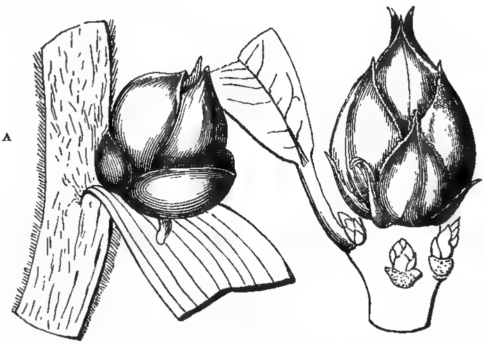
A  B

Fig. X.—A. Bulb of Tiger Lily contrasted with B. a Leaf-bud.

They are magazines in which certain plants store up the nutritive matter assimilated by the leaves. The identity of a bulb and a bud, in all essential circumstances, is obvious, if the

* The *axil* is the acute angle formed by a leaf and stem, at the origin of the former; all bodies growing within that angle are said to be *axillary*.

bud of any tree (Fig. X. B.) is compared with the bulbs of the Tiger Lily (Fig. X. A.)

Since leaf-buds are thus the parents of wood, one of the means of propagating the individual to which they belong, the origin of branches, and consequently the source of the development of leaves themselves, they may be considered the most important organs of vegetation, so far as any one organ can be called *most* important where all are so mutually dependent the one on the other, and so powerfully concur in maintaining the system of vegetable life, that it is difficult to abstract one part without impairing the efficiency of the remainder.

The office of the stem is, to convey the crude fluid obtained by the roots from the soil, and called *sap*, into the leaves for elaboration, and then to receive it back again. Sap is, originally, water holding in solution gaseous matter, especially carbonic acid, together with certain earths and salts, but as soon as it enters the stem, it dissolves the vegetable mucilage it finds there, and becomes denser than it was before; it is further changed by the decomposition of a part of its water, acquires a saccharine character, and, rising upwards through the whole mass of wood, and more especially the alburnum, takes up any soluble matter it passes among. Its specific gravity keeps thus increasing till it reaches the summit of the branches; by degrees, it is wholly distributed among the leaves. In the leaves it is altered, and then returned into the general system, more especially into the fruit, and the bark, through which it falls, passing off horizontally through the medullary rays into the interior of the stem, and fixing itself in the interior of the bark, especially of the root, when it undergoes various changes, the results of which are known under the name of vegetable secretions.

It may be said, that, in trees, the alburnum and liber have each two equally important offices to perform: the alburnum giving strength and solidity to the stem, and chiefly conveying sap upwards; the liber not only conveying sap downwards, but covering over the alburnum, protecting it from the air, and enabling it to form without interruption. The central wood is of little consequence, and may be destroyed, as it constantly is

in hollow trees; and the outer rind is of comparatively small importance, for it is continually perishing under the influence of the atmosphere: but liber and alburnum are the seats of vitality in trees and cannot be permanently injured without destruction to the plant.

If indeed this were absolutely the case it would be indispensable that liber and alburnum should be most carefully guarded; and so they are in nature by the thick integument of mere bark, which overlies them. But it continually happens that the usual vegetative processes are interrupted by accidents, while the power of repairing injuries is so great that many of the usual functions of a plant may be destroyed without serious injury, such functions being performed *ad interim* by other organs until the injury is repaired; so that although, under ordinary circumstances, the sap of exogens rises through the wood and descends through the liber, yet the simplicity of structure in plants is such, that, together with the permeability of their tissue, it enables them to propel their fluids by lateral instead of longitudinal communications. The trunk of a tree has been sawed through beyond the pith in four opposite directions; namely, from north to south, from west to east, from south to north, and from east to west, at intervals of a foot, so as completely to cut off all longitudinal communication between the upper and lower parts of the stem, as effectually as if those two parts had been dissevered; and yet the propulsion of the sap from the roots into the head of the tree, and *vice versâ*, went on as before: which could only have been effected by a lateral transmission of this fluid through the woody tissue. So when "ringing" is practised, and the alburnum is partially destroyed, the descending fluid diverges into the stratum of wood beneath the annulation; and when it has passed by, it again returns into its accustomed channels.

A striking example of this was given by Mr. Curtis in the *Gardeners' Chronicle* for 1846 (p. 597). It was the case of a Pollard Ash-tree (Fig. XI.) struck with lightning on the 7th or 8th of May, 1845, and thus deprived of the bark all round the trunk for a space of eight feet at fig. 3, and of three feet two inches at fig. 1. Nevertheless in July 1846

the tree was in full leaf as shown in the cut. In this case the descending sap must have either accumulated above the wound, or, which is

Fig. XI.—Decorticated Ash-tree.

more probable, must have reached the lower part of the system by passing through the wood itself, till it reached the point 2; as indeed Knight showed must happen in other but less striking instances of complete decortication (*Physiol. Papers*, p. 130), such as ringing.

Some curious experiments upon this subject were contrived by Mr. N. Niven (*Gardeners' Magazine*, vol. xiv.). In one case, he divested the stem of a tree of a deep ring of bark, and of the first twelve layers of wood below it (Fig. XII.); nevertheless the

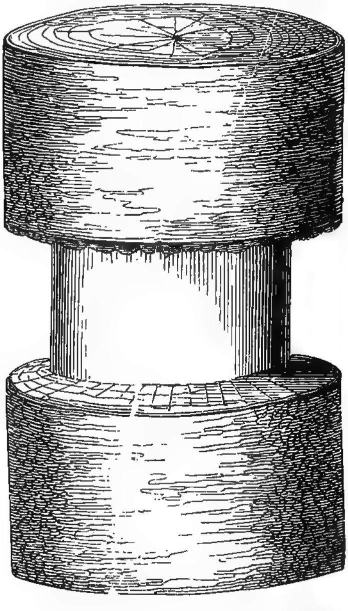


Fig. XII.—Ringed tree, having wood removed as well as bark.

tree continued to live and be healthy. From the exposed surface of the wood no sap made its appearance, except from a cut which had been inadvertently made with the saw on one side, to the depth of, perhaps, five or six layers of wood beyond the twelve actually removed. From that cut a flow of sap took place, and continued to run during the whole of the season in which the operation was performed. In this case, the sap cannot have ascended exclusively by the alburnum, but must have chiefly passed through the central wood.

In another case, by making four deep and wide incisions into the trunk of a tree (Fig. XIII.), and removing the centre, the upper part of the trunk was placed upon four separate pillars of bark

and alburnum; and the tree upon which the operation was performed continued to live for two years, after which it was not observed. In this instance, no doubt can be entertained

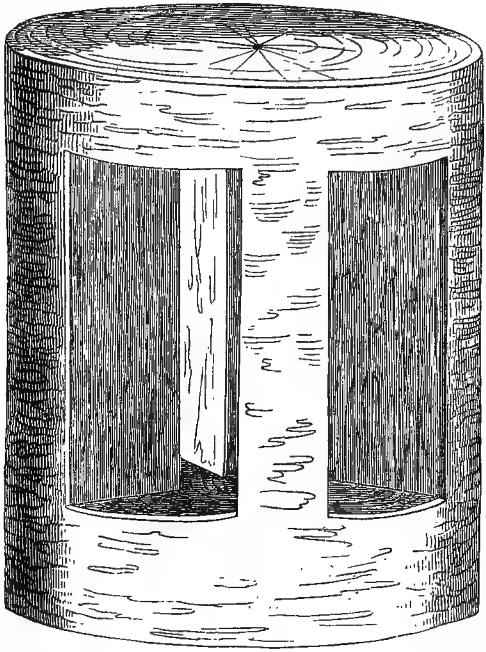


Fig. XIII.—Crucial incisions in the trunk of a tree.

that the whole of the sap was directed into the four pillars, after passing through which it was conveyed laterally both in ascent and descent until the whole system was again filled.

The cause of the *flow* of the sap appears to be the attraction of it by the leaves, which continually diminish its quantity; and the necessity that the sap abstracted should be replaced by a further supply sent upwards from the roots. The consequence of this is, that sap always begins to flow at the ends of branches, a circumstance which has led to the erroneous idea that it proceeds from above downwards through the alburnum. The flow of the sap must not, however, be confounded with the motion of the sap, which takes place in the winter as well as

in the summer, and is a mere impletion of the system, caused by the absorbing force of the roots, unaffected by the exhalation of the leaves.

Occasionally they discharge sap in such abundance from the wound that they are said to BLEED; and when the sap is red, as in Pergularia sanguinolenta, the discharge has the appearance of being identical with the bleeding of animals. When trees begin to grow in the spring, sap flows abundantly from their wounds; it may even be collected for fermentation, as occurs to the Birch-tree, whose juice, obtained by tapping, in the early spring, becomes converted into a sparkling wine; or, by boiling, the saccharine matter dissolved in sap may be collected in abundance, as is the case in North America with the Sugar Maple. If allowed to continue for too long a time such bleeding causes incurable debility or death. The roots of a tree will bleed as much as the stem; and with the same consequences. A case is mentioned by the Hon. Jas. Stuart Wortley of a very fine Birch-tree, whose roots were cut through in making a new walk near it. They were about five in number, and averaged about an inch and a half in diameter, and continued bleeding so incessantly for a fortnight, that the walk at the end of that time stood in puddles, and the sap still bubbled up through the gravel. The same circumstance was observed in lowering the ground near a large Walnut-tree, when some great roots having been cut through, so much bleeding took place in consequence that the tree died.

A third occurrence of the same nature has been recorded by Mr. Spencer, gardener to the Marquess of Lansdowne, at Bowood. In forming a new walk, he had occasion to cut through three large roots belonging to an adjoining Beech which remained exposed. Some time about the middle of March he observed the roots were bleeding considerably, and they continued to do so till the end of April, the *flow being materially influenced by the state of the weather*. By the beginning of April the bleeding was sufficient to saturate the walks. On examining the roots with an ordinary microscope, he observed the discharge proceeded from the whole of the exposed cells through the section; but, from the larger diameter of the vessels towards the exterior

of the root, the bleeding, as a natural consequence, was greatest at that part. He also remarked that bubbles of air were frequently formed on the cut surface, evidently showing that some kind of gas was present, either in the sap or in the cells. The discharge was perfectly visible to the naked eye, and in bright weather the microscope enabled him to see distinctly the *downward* passage of the sap, through *all* the root cells.

Such cases are doubtless much more common than is supposed. The cause of the phenomena was in part demonstrated more than a century since by Hales. In discussing the question of the circulation or non-circulation of the sap, this great experimentalist uses the following words ;— "We see in many of the foregoing experiments, what quantities of moisture trees do daily imbibe and perspire. Now the celerity of the sap must be very great, if that quantity of moisture must, most of it, ascend to the top of the tree, then descend, and again ascend, before it is carried off by perspiration. The defect of a circulation in vegetables seems in some measure to be supplied by the much greater quantity of liquor which the vegetable takes in, than the animal, whereby its motion is accelerated; for by Experiment 1st, we find the Sunflower, bulk for bulk, imbibes and perspires seventeen times more fresh liquor than a man every twenty-four hours. Besides, Nature's great aim in vegetables being only that the vegetable life be carried on and maintained, there was no occasion to give its sap the rapid motion which was necessary for the blood of animals. In animals, it is the heart which sets the blood in motion, and makes it continually circulate; but in vegetables, we can discover no other cause of the sap's motion but the strong attraction of the capillary sap vessels, assisted by the brisk undulations and vibrations *caused by the sun's warmth,* whereby the sap is carried up to the top of the tallest trees, and is there perspired off through the leaves: but when the surface of the tree is greatly diminished by the loss of its leaves, then also the perspiration and motion of the sap is proportionably diminished, as is plain from many of the foregoing experiments; so that the ascending velocity of the

sap is principally accelerated by the plentiful perspiration of the leaves."

The sap then ascends in consequence of an attracting force exercised from above downwards by the foliage of plants. But it is evident that this is only a partial explanation of the phenomenon; for it does not account for the ascent of sap in winter when leaves are absent. In order to explain that fact we must have recourse to the action of endosmose, a force the effect of which is to produce propulsion. A tree may be assumed to be a combination of hollow tubes freely communicating with each other, and enclosed in a skin *through which fluids are capable of being absorbed* on the one hand and expelled on the other. If we conceive a body of this kind, in which the tubes are nearly empty, to have its lower extremity plunged in water, the absorbing power of the skin at that part will begin to introduce the water into the interior, and this continuing to go on for a sufficient time, the tubes must necessarily become at last filled with water rising upwards from below. To effect this, no attracting force at the upper end of the cylinder was necessary; every particle of water which was absorbed by the lower end, having driven before it a corresponding volume of the water previously existing in the apparatus. Under the influence of this operation the tubes would in time become full, and if unelastic the introduction of more water would be impossible. But if such tubes and the skin that encloses them were elastic and extensible, then any such further quantity of water might be introduced as the apparatus could receive without bursting. If we then suppose that the one end of the apparatus were cut open the sides of the tubes would collapse, and the water would be forced out till there was no more left than the tubes held in their original unstretched condition. A tree is just such an apparatus. Its tubes are nearly empty at the fall of the leaf. During winter the roots absorb water from the soil and fill the tubes again. By the arrival of spring they are filled almost to bursting, and then if the stem is cut it bleeds; or if the roots are cut they bleed. Bleeding ceases as the leaves unfold. The Vine, the Walnut, the Birch, are all as incapable of bleeding as other trees when

their leaves are formed; because the leaves gradually empty the tubes, put an end to their distension, and prevent its recurrence so long as they remain in an active state.

The excessive loss of sap in the above-mentioned cases would not have taken place if the roots had been wounded in the summer or autumn. It is probable, moreover, that the bleeding was increased by the unusual coldness of the spring in which these instances occurred. Hales himself was aware that sap falls back at night in consequence of the contraction of the tubes by cold; Mr. Knight observed the same fact: and it has more recently been proved experimentally by M. Biot. It may therefore be supposed that excessive cases of bleeding occur, because, in addition to the natural contraction of the tubes of the wood, their mechanical contraction by unusual cold has to be taken into account.

CHAPTER V.

ACTION OF LEAVES.

THEIR NATURE, STRUCTURE, VEINS, EPIDERMIS, STOMATES.—EFFECT OF LIGHT.—DIGESTION OR DECOMPOSITION OF CARBONIC ACID.—INSENSIBLE PERSPIRATION.—FORMATION OF SECRETIONS.—FALL OF THE LEAF.—FORMATION OF BUDS BY LEAVES.

A LEAF is an appendage of the stem of a plant, having one or more leaf-buds in its axil. In those cases where no buds are visible in the axil, they are, nevertheless, present, although latent, and may be brought into development by favourable circumstances. As this is a universal property of leaves, to which there is no known exception, it follows that all the modifications of leaves, such as scales, hooks, tendrils, &c., and even the floral organs, hereafter to be described, may have the same property.

Buds are, however, formed with difficulty by such modified leaves as brown scales or mere membranous expansions, even although the latter are capable of assuming the usual condition of leaves when anything occurs to increase their force of development. The more green, the more succulent, the more perfectly organized a leaf is, the greater is its power of forming axillary buds; and *vice versâ*. That the power of forming buds really exists among leaves even when most unlike their usual state is proved by such examples as that at p. 90 of this work, where they are appearing even from among carpellary leaves. In the Author's *Elements of Botany*, p. 75, a case is figured of buds from the axils of leaves in the state of petals, and he has now before him an example of a Clematis Sieboldi, received from Mr. Wilson, Gardener to the Earl of Burlington, in which six buds are formed in the axils of stamens. Such examples are, however, wholly exceptional.

All leaves arrive at their final condition through intermediate states; and if their growth is arrested by any cause, whether

constitutional or accidental, then they remain fixed in the state in which the arrest occurred. Owing to this cause, we find them in the form of points, scales, straps, or perfect organs on the same plant.

The history of their development has been explained by M. Trécul better than by any other writer. The following is the substance of his remarks:—The stem terminates in a very delicate cellular tumour (growing point) from the sides of which the leaves are developed. These first present themselves in the shape of still smaller tumours, alternate, opposite, or verticillate. When opposite or verticillate leaves are to be united at the base, a circular elevation precedes them on the axis; when they are not confluent the tumours are isolated; lastly, when alternate leaves are sheathed, the sheath either takes its rise from a circular eminence round the stem, or else the rudimentary tumour which first shows itself, enlarges, and finally embraces the stem. Leaves are developed after four principal types, the *centrifugal* (from below upwards), the *centripetal* (from above downwards), the *mixed* and the *parallel*. In the CENTRIFUGAL formation all the parts are formed from below upwards, the leaf is pinnate, and furnished with stipules, the petiole (rachis) first makes its appearance; on its sides come the stipules, then the lower pair of leaflets, then the second pair, then the third, fourth, and so on. If the leaf is supra-decompound the primary tumour or rachis in growing throws out secondary petioles, and these latter tertiary ones, &c., according to the composition of the leaf at the extremity of which the leaflets form. The development of simple leaves may be explained by that of the Lime-tree. This leaf commences with a rudimentary tumour at the apex of the stem. This tumour lengthens and enlarges, leaving at its base a contraction which represents the petiole. The blade, at first entire, is soon divided from side to side by a sinus. The lower lobe is the first secondary nervure; the upper part is subdivided in the same manner five or six times, in order to form as many nervures of the same sort. About the time that the third or fourth upper lobe makes its appearance, the lower one, which was formed first, having also extended, becomes sinuous at its edges. These sinuosities are the indications of the origin of five or six ramifications of the lower nervure. At this period the leaf is furnished with as many toothings as there are nervures. But in a short time fresh toothings appear between those first formed, these correspond with the development of as many secondary nervures. The nervures which unite transversely with the adjoining nerves are produced at the same time. The hairs which cover the under surface of the leaf are also formed from below upwards. Thus the various kinds of nervures in the leaf of a Lime-tree develope like the different sorts of shoots in the tree that bears them. To leaves developed CENTRIPETALLY belong those of

Burnet, Roses, &c. In these plants the terminal leaflet is produced before all the others, the pair of leaflets nearest the apex of the leaf next make their appearance, then the second pair, the third, and so on, from the apex to the base. All digitate and radiate leaves belong to the centripetal mode of formation. In Potentilla reptans, &c., not only do the leaflets grow from the top downwards, but their secondary nervures and toothings appear in the same way. In plants belonging to the MIXED TYPE, the two preceding modes of development are combined. The lobes of the leaves of Acer platanoïdes, &c., and the midribs of those lobes which are digitate, form from above downwards; the lower lobes are produced last, but the secondary nervures and the toothings are developed like those of the Lime-tree. The PARALLEL FORMATION is common to many Endogens. All the nervures are formed in a parallel manner; but in this, as well as in the case of dicotyledonous plants, the sheath is the first that makes its appearance (Carex). The leaf lengthens more especially by the base of the blade, or that of the petiole when it exists (Chamærops); the sheath, often extremely small, does not increase in growth till a later period; the same holds true with regard to Exogens when they have a sheath. As regards the growth of leaves, which has been confounded with their mode of formation, M. Trécul has shown that all leaves which are furnished with sheaths, or those which are very much protected by having their lower portions enveloped with other organs, grow most by the base; on the other hand, those of which the whole petiole is exposed to the air at a very early period, in consequence of the stem lengthening, grow much more towards the upper part of the petiole (Tropæolum majus, Æsculus, &c.) Nevertheless, there is a short space near the insertion of the petiole in the blade where the increase in length is less than a little lower down.

Considered with respect to its anatomical structure, a leaf is an expansion of the bark, consisting of cellular substance, among which are distributed veins. The former is an expansion of the rind; the latter consist of woody matter arising from the neighbourhood of the pith, and from the liber. As the tissue forming veins has a double origin, it is arranged in two layers, united firmly during life, but separable after death, as may be seen in leaves that have been lying for some time in water. Of these layers, one is superior and arises from the neighbourhood of the pith, the other inferior and arises from the liber; the former maintains a connection between the wood and leaf; the latter establishes a communication with the bark. Since sap, or ascending fluid, rises through the wood, and more especially the alburnum, afterwards descending through the

liber, it follows from what has been stated, that a leaf is an organ of which the upper system of veins is in communication with the ascending, and the lower system with the descending, current of sap.

This statement must be understood to express nothing more than what may be called the typical condition of a leaf, and especially of such as are thin and abundantly furnished with veins. In succulent plants no layers can be distinguished, but the veins are dispersed among pulp; in membranous leaves it is uncertain whether more than one layer is present; finally in some there are three distinct layers, as in Brexia spinosa, which has a middle system of coarsely and irregularly netted veins, and immediately below both the upper and lower skin a layer of much finer and closer oblique veins.

A leaf has moreover a skin, or epidermis, drawn over it. This epidermis is often separable, and is composed of an infinite number of minute cells or cavities, originally filled with fluid, but eventually dry and filled with air. In plants growing naturally in damp or shady places it is very thin; in others inhabiting hot, dry, exposed situations, it is hard and thick; its texture varies between the two extremes, according to the nature of the species. The epidermis is pierced by numerous invisible pores, called stomates, through which the plant breathes and perspires. Such stomates are generally largest and most abundant in plants which inhabit damp and shady places, and which are able to procure at all times an abundance of liquid food; they are fewest and least active under the opposite conditions. It will be obvious, that, in both these cases, the structure of a leaf is adapted to the peculiar circumstances under which the plant to which it belongs naturally grows. Now as this structure is capable of being ascertained by actual inspection with a microscope, it follows, as a necessary consequence, that the natural habits of an unknown plant may be judged of with some certainty by a microscopical examination of the structure of its epidermis. The rule will evidently be, that plants with a thick epidermis, and only a few small stomates, will be the inhabitants of situations where the air is dry and the supply of liquid food small; while those with a thin epidermis, and a great number

of large stomates, will belong to a climate damp and humid; and intermediate degrees of structure will indicate intermediate atmospherical and terrestrial conditions. It is, however, to be observed, that the relative *size* of stomates is often a more important mark in investigations of this nature than their *number;* those organs being in many plants extremely numerous, but small and apparently capable of action in a very limited degree; while in others, where they are much less numerous, they are large and obviously very active organs. Thus the number of stomates in a square inch of the epidermis of Crinum amabile is estimated at 40,000, in that of Mesembryanthemum at 70,000, and of an Aloe at 45,000; the first inhabiting the damp ditches of India, the last two natives of the dry rocks of the Cape of Good Hope: but the stomates of Crinum amabile are among the largest that are known, and those of Mesembryanthemum and Aloe are among the smallest, so that the 70,000 of the former are not equal to 10,000 of the Crinum. Again the Yucca aloifolia has four times as many stomates as a species of Cotyledon in my collection, but those of the latter are about the $\frac{1}{750}$ of an inch in their longer diameter, large and active, while the stomates of the Yucca are not more than $\frac{1}{2500}$ of an inch long in the aperture, and comparatively inert. The Yucca, therefore, with its numerous stomates, has weaker powers of perspiration and respiration than the Cotyledon.

A leaf, then, is an appendage of the stem of a plant, consisting of an expansion of the cellular rind, into which veins are introduced, and enclosed in a skin through which respiration and perspiration take place. It is in reality a natural contrivance for exposing a large surface to the influence of external agents, by whose assistance the crude sap contained in the stem is altered and rendered suitable to the particular wants of the species, and for returning into the general circulation the fluids in their matured condition. In a word, the leaf of a plant is its lungs and stomach, traversed by a system of veins.

It is well known to Gardeners that the efficiency of leaves is much promoted by their being kept perfectly clean. The great cause of the unhealthiness of plants in towns is the amount of dirt which unavoidably

collects upon their surface. If such impurities are constantly washed off, plants will grow as well in cities as in country places. This was found experimentally by M. Garreau, who in the course of his inquiries into the functions of the skin of plants, found that soap and water had great value; plants well washed acquiring a power of absorption much beyond what they possessed in their unwashed condition. Thus the rate of absorption in the Tangiers Ferula was as 4 to 0 after ablution; and in the yellow Gentian as 30 to 20. In like manner, the petals of the Pæony took up five and six times as much after as before being cleaned; and the leaves of the Lilac, Lily of the Valley, Ivy, and Clematis about twice as much. It was found that soap and water had a far greater cleansing effect than mere water; thus, a Fig-leaf, which had been lathered, absorbed 90 parts, while after a mere water-bath it took up only half the quantity; and a bramble, which soap and water provided with 130 parts of water absorbed, could only consume 10 parts when cleaned with water alone. It was thus shown that perfect cleanliness is as indispensable to plants as to animals, and that dirty gardening is necessarily bad gardening. Plants breathe by their leaves; and if their surface is clogged by dirt of whatever kind, their breathing is impeded or prevented. Plants perspire by their leaves; and dirt prevents their perspiration. Plants feed by their leaves, and dirt prevents their feeding. So that breathing, perspiration, and food, are fatally interrupted by the accumulation of foreign matters upon leaves. Let any one, after reading this, cast an eye upon the state of plants in sitting-rooms, or ill-kept greenhouses; let them draw a white handkerchief over the surface of such plants, or a piece of smooth white leather, if they desire to know how far they are from being as clean as their nature requires. Half the business of a good gardener consists in sponging and washing the leaves of his plants.

As the leaf is an extension of the rind of a stem, its epidermis is also an extension of the skin of the same part; and hence it is that in plants which produce no true leaves, such as the Stapelia, the office of the leaf is performed by the rind and epidermis of the bark.

The functions of respiration, perspiration, and digestion, which are the particular offices of leaves, are essential to the health of a plant; its healthiness being in proportion to the degree in which these functions are duly performed. Consequently, whatever tends to impede the free action of leaves, tends also to diminish the healthiness of a plant.

One of the translators of this work objects to the word digestion employed in the preceding paragraph, upon the ground that the essen-

tiality of digestion in the animal organism consists in the conversion of food into a homogeneous fluid, a function which plants do not exercise. But digestion also means the conversion of raw materials into substances capable of being assimilated or rejected; and in that sense the word is here employed.

These functions are performed by means of the vital forces of vegetation, which we cannot estimate or comprehend, assisted by the influence of an external agent, the nature of whose action may be understood from its effects. That agent is solar light.

It is the property of solar light, when striking upon the leaf of a plant, either directly or indirectly to cause: 1. A decomposition of carbonic acid; 2. An extrication of oxygen; and, 3. Insensible perspiration. By their vital forces plants appear to decompose water, independently of the action of light.

Carbonic acid is originally introduced into the interior of a plant, either dissolved in the water it imbibes by its roots, or by attraction from the atmosphere, or by the combination of oxygen resulting from the decomposition of water or from other sources, with the carbon in its interior. When a leaf is exposed to the direct influence of the sun, it gives off oxygen, by decomposing the carbonic acid; whereupon the carbon remains behind in the interior of the leaf in a solid state. In the total absence of solar light, there is little or no extrication of gaseous matter, and what little is given off will be found to be carbonic acid, which plants exhale at all times in small quantities; oxygen however, which was before expelled, is inhaled. Hence plants decompose carbonic acid during the day, and acquire it again during the night, and, during the healthy state of a plant, the decomposition by day, and recovery by night, of this gaseous matter, is perpetually going on. The quantity of carbonic acid decomposed is in proportion to the intensity of the light which strikes a leaf, the smallest amount being in shady places; and the healthiness of a plant is, *cæteris paribus*, in proportion to the quantity of carbonic acid decomposed; therefore, the healthiness of a plant should be in proportion to the quantity of light it receives by day.

"Most physiologists have connected the exhalation of carbonic acid during night with the absorption of oxygen from the atmosphere, and consider this function as the real respiration of plants, which (as we know) produces in animals a decarbonisation of the blood. There is scarcely an opinion which rests on such a feeble basis. The water received by roots contains carbonic acid, which is not decomposed in the absence of light, but remains dissolved in the sap which pervades all parts of a plant; and every moment, along with the water evaporating through the leaves is a proportionate amount of carbonic acid expelled. Soil in which plants vegetate luxuriantly contains a certain quantity of moisture (an indispensable condition of their life), and such a soil is never deficient in carbonic acid, either derived from the atmosphere or from the putrefaction of vegetable matter. No water, either rain or that of springs, is free from carbonic acid; and at no period of the life of a plant does the capability of its roots to absorb moisture, and consequently air and carbonic acid, altogether cease. Can it therefore surprise us that carbonic acid, conjointly with the evaporating water of the plant, is returned to the atmosphere, when the cause of the fixation of carbon, viz. light, is deficient? That exhalation of carbonic acid is as unconnected with the process of assimilation and with the life of a plant as the absorption of oxygen. They do not bear the least relation to each other; the one is a purely mechanical, the other a chemical process. A wick of cotton shut up in a lamp which contains a fluid impregnated with carbonic acid will be in just the same position as a living plant in darkness. Water and carbonic acid are absorbed by the power of capillary attraction, and both evaporate again on the surface of the wick."—*Liebig's Organic Chemistry*, 1840. The foregoing passage is objected to by some physiologists who do not believe that carbonic acid can pass through a plant without being decomposed. And Mr. Haseldine Pepys, in his careful experiments on *Vegetable Respiration*, arrived at the conclusion that no carbonic acid whatever is parted with either by night or day.

Whether plants do or do not give off some small quantity of carbonic acid, this at least is certain, that they do not in this way deteriorate the atmosphere in any appreciable degree. If there is one absurdity among popular prejudices greater than another, or leading more to privation of comfort when most wanted, it is that of fancying that growing plants vitiate the air of an apartment by the carbonic acid they emit. The reasoning on which this is founded is as follows:—1. Growing plants form carbonic acid in their interior, by absorbing oxygen from the atmosphere; they thus rob the air of that which is most necessary to animal life, and therefore they are prejudicial, especially to sick persons. 2. Growing plants also give out carbonic acid or fixed air, a pernicious gas, in which animal life cannot be maintained; therefore, they should be expelled from all apartments, espe-

cially those occupied by invalids: for how can a physician, careful of the health of his patient, permit the presence of objects which are thus incessantly contaminating the air? It may be true that plants destroy oxygen gas and form carbonic acid; but if everything that produces that effect was also to be expelled, the patient herself must be separated from herself, for a human being consumes more oxygen, and gives off more carbonic acid, in five minutes, than all the plants in a sitting-room in twenty-four hours. It is wonderful that this notorious fact should not have removed the prejudice about plants deteriorating the air of sitting-rooms. It is still more surprising that the idea should be retained at the present day, at least when it is also well known that plants, in fact, purify instead of vitiating the atmosphere. If it is true that they do a minute amount of harm, by destroying *some* vital air, and producing *some* fixed air, it is equally true that they do a great amount of good by producing a *large quantity* of vital air, and destroying a *large quantity* of fixed air. It is one of the most beautiful provisions we know of in nature, that the deleterious air breathed forth by animals is purified and rendered salubrious by plants; if it were otherwise, the globe would become uninhabitable. But every leaf, every blade of grass—nay, the finest of the green silken threads that float about in pools of water, is incessantly occupied, during daylight, in effecting this most important change of pestilent air into an atmosphere of life. One thing, however, is to be observed regarding plants. Although it is false that they contaminate the air of a sitting-room, in the way that is supposed, or in any other way, in the majority of cases, yet it is certain that unpleasant effects are occasionally produced upon peculiar constitutions by their *odour*. The flowers of the glaucous Magnolia are said to bring on sickness and headache; the Jonquil, the Tuberose, and the Lilac, are apt to cause faintness—an effect, indeed, which we have seen produced by a few Violets, even in the open air; and Linnæus mentions a case of death, said to have been occasioned by sleeping in a room where the Oleander was in flower. But this class of effects does not in any way justify the exclusion of all plants from sitting-rooms; it only shows the necessity of avoiding the presence of such as have powerful and oppressive odours.

But, while this is true as a general axiom, it is necessary to observe that some plants are naturally inhabitants of shady situations, and are so organised as to be fit for such places and for no others: plants of this description will not endure full exposure to the sun; not because an abundant decomposition of carbonic acid is otherwise than favourable to them, but because their epidermis allows the escape of water too freely by insensible perspiration, under the solar stimulus.

As far as is yet known, solar light alone has the power of producing any practical effect upon vegetation. That of the moon has, however, been shown to be not without influence. That the moon has a great mechanical effect upon our globe is undisputed. Of this, we need not say that the perpetually alternate ebbing and flowing of the tide affords the most evident proof. But, whilst the effects of the moon are admitted to be extremely powerful in this respect, the influence of her light, except as regards illumination, has been often considered by scientific men as inappreciable; and the proverbs to the contrary, current among the unlearned, have been accordingly estimated as popular errors. It has, however, been at last demonstrated that the moon's rays are very far from powerless. We learn from a note by M. Zantedeschi (*Comptes Rendus*, October, 1852), that these rays do affect vegetation. This philosopher states that, "the influence, physical, chemical, and physiological of the moon's light, which has hitherto been the object of so much research and speculation amongst scientific and agricultural writers, has been recently investigated by him in consequence of his having had occasion to give a historical summary of the works on the subject. In the course of his inquiries he found it necessary to clear many doubtful points, in doing which his attention was forcibly arrested by the movements exercised in mere moonlight, under certain circumstances, by the organs of plants; and this led him to make the whole subject a serious and profound study. His observations were commenced in 1847, in the Botanic Garden at Venice; they were continued in 1848 in the Botanic Garden at Florence, and at Padua in 1850, 1851, and 1852. In the whole series of his experiments M. Zantedeschi always remarked certain motions in plants having a delicate organization as soon as they were brought under the influence of the lunar rays. In those experiments the rays were always diffused, being neither concentrated by lens nor mirror. Such movements could not be obtained by the action of heat, in whatever way thermal influences were applied. It was in vain to elevate or depress the temperature: in the absence of moonlight the phenomena in question could not be elicited.

The plants on which M. Zantedeschi principally experimented were Mimosa ciliata, Mimosa pudica, and Desmodium gyrans. He always took great care to determine exactly the position of the leafstalks and leaflets of the plants after they had been exposed to the open air, and before they were directly illuminated by the lunar rays. He thus avoided any causes of error which might have arisen from the imperceptible motion of the air, or from a slight change of temperature; and he satisfied himself fully that the effects observed did result entirely from the action of the rays of light from the moon. Without entering into minute details, it is sufficient to say that the results were ascertained when the temperature of the air was 70° Fahr.; and when Saussure's hygrometer indicated a medium state of humidity. Under such conditions, the leafstalks of Mimosa ciliata were raised half a centimetre, or about four-tenths of an inch; those of the Mimosa pudica were raised one inch and two-tenths; whilst the leaflets of Desmodium gyrans exhibited distinct vibrations. It was thus demonstrated that moonlight has the power, *per se*, of awakening the Sensitive Plant, and consequently that it possesses an influence of some kind on vegetation. It is true that the influence was very feeble, compared with that of the sun; but the action, such as it is, is left beyond further question. This being so, the question remains; what is the practical value of the fact? It will immediately occur to the reader that possibly the screens which are drawn down over hothouses at night, to prevent loss of heat by radiation, may produce some unappreciated injury by cutting off the rays of the moon, which Nature intended to fall upon plants as much as the rays of the sun.

Even artificial light is not wholly powerless. De Candolle succeeded in making Crocuses expand by lamp-light, and Dr. Winn, of Truro, has suggested that the oxy-hydrogen lamp may be made subservient to horticulture in the long dark days of winter. It does not, however, appear that this hypothesis rests upon any experimental basis.

The mere fact of plants absorbing water from the earth would render it probable that they have some means of parting with a portion of it by their surface; but that they do perspire

is susceptible of direct proof, and is by no means a mere matter of inference. We do not indeed see vapour flying off from the surface of plants; neither do we from that of animals, except when the air is so cold as to condense the vapour; yet we know that in both cases perspiration is perpetually going on, and it would appear that in plants it takes place more abundantly than in animals. If a plant covered with leaves is placed under a glass vessel, and exposed to the sun, the sides of the vessel are speedily covered with dew, produced by the condensation of the insensible perspiration of the plant. If the branch of a plant is placed in a bottle of water, and the neck of the bottle is luted to the branch, so that no evaporation can take place, nevertheless the water will disappear; and this can only happen from its having been abstracted by the branch which lost it again by insensible perspiration. Hales, an excellent observer, devised many experiments connected with this subject;* among others the following, which he relates thus:—"August 13. In the very dry year 1723, I dug down two and a half feet deep to the root of a thriving baking Pear-tree, and laying bare a root half an inch in diameter (Fig. XIV.), I cut off the end of the root at *i*, and put the remaining stump (*i n*) into the glass tube *d r*, which was an inch in diameter, and eight inches long, cementing it fast at *r*; the lower part of the tube *d z* was eighteen inches long, and a quarter of an inch diameter in bore. . . . Then I turned the lower end of the tube (*z*) uppermost, and filled it full of water, and then immediately immersed the small end *z* into the cistern of mercury at the bottom, taking away my finger which stopped up the end of the tube *z*. . . . The root imbibed the water with so much vigour, that in six minutes' time the mercury was raised up the tube *d z* as high as *z*, namely, eight inches. . . . The next morning at eight o'clock the mercury was fallen to two inches in height, and two inches of the end of the root *i* were yet immersed in water. As the root imbibed the water, innumerable air bubbles issued out at *i*, which occupied the upper part of the tube at *r* as the water left it." On another occasion

* See *Vegetable Staticks*, London, 1727.

he planted a sunflower three and a half feet high in a garden pot, which he covered with thin milled lead, cementing all the joints so that no vapour could escape except through the sides

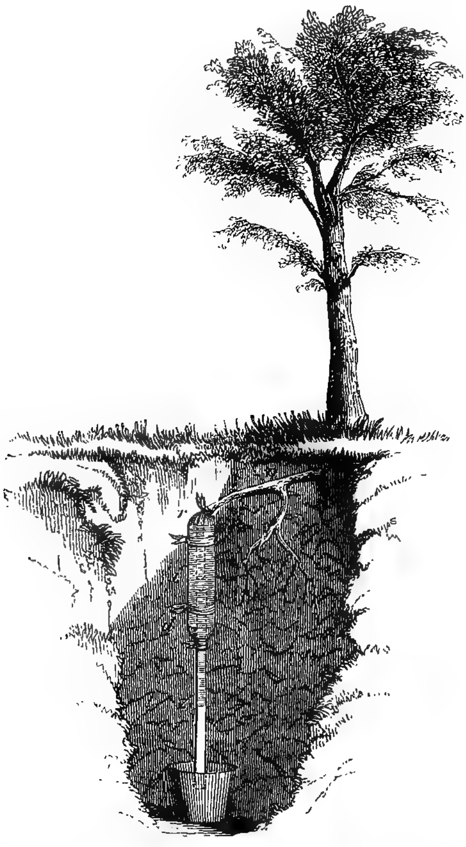


Fig. XIV.—Hales's experiment to determine the amount of perspiration.

of the pot and through the plant itself; but providing an aperture, capable of being stopped, through which the earth in the pot could be watered. After fifteen days, viz., from July 3 to August 8, he found, upon making all necessary allowances for waste, that this sunflower plant, three feet and a half high,

with a surface of 561·6 square inches above the ground, had perspired as follows:—

	Ounces Avoirdupois.
In twelve hours of a very dry warm day	30,
On another day	20,
In a dry warm night without dew	3,
In a night with some small dew	0;

and that when the dew was copious, or there was rain during the night, the plant and pot were increased in weight two or three ounces. Other persons have instituted other experiments of a similar nature, the result of all which is, that the insensible perspiration of plants is very considerable. Hales says his sunflower perspired seventeen times more than a man. There is, however, this important peculiarity in vegetable perspiration, that it takes place only or principally in sunlight. The last experiment shows that, while the sunflower was losing from twenty or thirty ounces of water daily during the day, it lost only three ounces during the night without dew, and that there was no loss whatever if a slight dew were present. Here it is probable that the small amount which was lost at night was parted with by the sides of the garden pot, and that the plant itself lost nothing; for it is in evidence that the perspiration of plants is in proportion to the quantity of sunlight that strikes them, and that in darkness they perspire little or not at all.* It is no doubt true, that in a dry atmosphere plants will lose their water day and night; but it is equally certain that under such circumstances they will lose very much more by day than by night. They will, however, lose much more by day in a dry atmosphere in a given time, than they will in an atmosphere abounding in moisture.

Although perspiration thus appears to be principally excited by the solar rays, and to be in a given plant in proportion to their intensity, yet we are not authorised in concluding that perspiration is not increased or diminished by the medium in

* M. De Candolle distinguishes between *exhalaison*, or perspiration, which is a vital action, and *deperdition* or evaporation, which is merely physical. But the latter is too small in amount to be worth taking into account for practical purposes.

which a plant grows. Submerged in water, perspiration is necessarily arrested; in an ordinary atmosphere, it will be in proportion to the quantity of elastic vapour the atmosphere may contain; and it is probable, although there are no experiments upon the subject, that it is increased in proportion to the rarefaction of the air.

Among the experiments of M. Garreau to which allusion has been already made, was one on the relative amount of perspiration by the two surfaces of ordinary foliage. Leaves growing on healthy plants were selected, and a circular portion inclosed between two closely fitting glass receivers, so arranged that the leaf formed the division between the two glasses—the upper surface was in the one glass, whilst the under surface of the leaf was in the other. The quantity of moisture given off was ascertained by placing in each glass a weighed portion of dry chloride of calcium, which, being very greedy of moisture, would absorb all the vapour as fast as the surface of the leaves gave it out. The result of this experiment was that the lower surface of leaves gives off, from an equal quantity, three times as much as the upper surface; sometimes the proportion was as high as five to one; and the ratio was independent of the position of the leaf itself. This exhalation of water has some connection with the number and size of the stomates, but is by no means wholly dependent on it, as there is evidently a large quantity of water given off independently of them. The evaporation is most abundant along the course of the nerves, and in those parts of the epidermis, on which there is the least quantity of oily matter. Hence it is apparent why carefully washing with soap and water proves so beneficial (see p. 58). The operation increases greatly the power of evaporation.

All such experiments teach us that under ordinary circumstances the growth of a plant causes the formation and development of certain substances, which in time fill up its pores, check perspiration, and consequently interfere with the nourishment and further growth of the plant. But, on the one hand, it is possible that in hot weather these matters may be useful in checking extreme perspiration, and in diminishing for the time the powers of the plant to absorb too much food from the air, or to part with water and oxygen too rapidly. On the other hand, the effect of rain must be to wash away a portion of these deposits, and so to favour the perspiration and consequent growth of the plant. Moreover, as the more heat a plant is exposed to, the more it perspires, and the faster it grows, the greater will the tendency be to fill up its pores; so it follows that when plants are exposed to great heat in a close house, and are not washed or syringed, they are placed in an unnatural condition, where the care of the gardener defeats, to some extent, the object which he has in view.

Since a plant does not perspire at night, and since its absorbing points, the roots, remain during that period in contact with the same humid medium as during the day, they will attract fluid into the system of the plant during the night, and, consequently, the weight of the individual will be increased, as Hales found to be the case. In like manner, if plants in the shade are abundantly supplied with moisture at the roots, they also will gain more than they can lose; and, as this will be a constant action, the result must necessarily be to render all their parts soft and watery.

It is evident, from what has been stated, that leaves must derive the food they digest from the earth through the medium of the roots, and from the air; and that they, while alive, maintain a kind of perpetual sucking action upon the stem, which is communicated to the spongelets. That this must be of a very powerful nature is apparent from the fact, that the smallest leaf at the extremity of the branch of a lofty tree must assist in setting in action the absorbing power of roots, at a distance equal, perhaps, to three thousand times its own length. If this reciprocal action is not maintained without interruption, and if anything occurs to check it during the period of vegetation, the plant will suffer in proportion to the amount of interruption. For example, if the roots are placed in a warmer medium than the branches, and are thus induced to absorb fluid faster than the slower action of the leaves can consume it, the superfluous sap will burst through the stem and distend its tissue till the excitability is impaired or destroyed. Or if, on the other hand, a branch is caused to grow in a warm medium, while the roots remain in a very cold medium, the former will consume the liquid sap faster than the latter can supply it, and the consequence will be, that the leaves will die, or the fruit will fall off, or the flowers be unable to set their fruit, from want of a constant and sufficient supply of food; or the fruit will shrivel, or, as it is said, will "shank." Not that it is necessary for the temperature of the earth and air to be equal, for this does not happen in nature; but it is requisite that they should have some near relation to each other.

It is generally, however, believed, that leaves absorb fluid

from the air. Their stomates appear well adapted for that purpose, by their position in most abundance on the under side of leaves; and the possibility of recovering drooping or sickly plants, by syringing their epidermis copiously, seems to render this fact almost certain. It is, however, imagined by some, that leaves have no power of absorbing water, even in an elastic state; and that the renovation of plants by syringing is merely owing to a diminution of perspiration, which is improbable.

It is to the action of leaves,—to the decomposition of their carbonic acid, and of their water; to the separation of the aqueous particles of the sap from the solid parts that were dissolved in it; to the deposition thus effected of various earthy and other substances, either introduced into plants, as silex and metallic salts, or formed there, as the vegetable alkaloids; to the extrication of nitrogen; and, probably, to other causes as yet unknown,—that the formation of the peculiar secretions of plants, of whatever kind, is owing. And this is brought about principally, if not exclusively, by the agency of light. Their green colour becomes intense, in proportion to their exposure to light within certain limits, and feeble, in proportion to their removal from it; till, in total and continued darkness, they are entirely destitute of green secretion, and become blanched or etiolated. The same result attends all their other secretions; timber, gum, sugar, acids, starch, oil, resins, odours, flavours, and all the numberless narcotic, acrid, aromatic, pungent, astringent, and other principles derived from the vegetable kingdom, are equally influenced, as to quantity and quality, by the amount of light to which the plants producing them have been exposed.

It is evident that the possibility of the downward distribution described in the previous paragraph rests upon the certainty that elaborated sap descends and is dispersed through the system. That this occurs is so certain, that it would have been needless to maintain it by further proof if some modern naturalists had not ventured to call it in question. To deny it is tantamount to questioning the existence of wood, or its formation as it appears to our eyes when the bark is stripped from a young growing shoot; as in a Lilac for example. In such a case new wood can be demonstrated to descend from each leaf downwards, till it is lost among the multitude of descending currents.

Upon this has been built the theory that wood grows downwards from leaves—which is now known to be erroneous; but although wood does not descend from leaves, it is certain that the organised matter out of which wood is formed does descend. If, indeed, the descent of elaborated sap is denied, it becomes impossible to explain why, when a *ring* of bark is removed from a branch, the new growth takes place principally on the upper edge of the wound and very slightly on the lower; and why gum, prepared by the leaves of a Potato, is afterwards found in the tubers, in the final form of starch. It is impossible for those who have any practical acquaintance with living plants not to agree with Prof. Mohl (*The Vegetable cell.* p. 71, English edition), that a denial of a descending current of sap in bark is quite incomprehensible. Certainly, as he says, it is no improvement upon the theory which men attempt to cast aside to say that increased growth above an annular wound is explained by artificial interruption of the upward current of crude sap, in consequence of which the fluids contained in the upper part of the plant must soon become greatly concentrated and potential for development. "When we can succeed in fattening an animal by depriving it of a portion of its accustomed food this explanation may be received as satisfactory."

This explains why there is usually more wood on the south side of a tree than on the north; and why depriving trees of their branches (and leaves) is invariably attended by a diminution of the quantity of timber.

Upon this curious subject some of the best observations are those of Van Hall, as recorded in one of the reports of the Ray Society. This gentleman remarked that the growth of trees in thickness only commences after the leaves are capable of fulfilling their functions; this was proved by all his measurements. The influence of the leaves upon the increase of trunks in thickness exhibited itself most distinctly in the Italian Poplar. On one of these trees being deprived of almost all its branches, in the month of March, the increase in thickness was proportionably slight during the months of June and July. The growth of a Lime-tree, on the other hand, in which the side branches, also those lower down on the trunk, as well above as beneath the point of measurement, had, for the greater part, been purposely left, was considerable, and increasing every year. An experiment was made with two equal sized Oaks, situated under the same circumstances; all the lateral branches were taken from one and left on the other; the result was, that the increase of thickness, in the tree which had not been pruned, was much more considerable than in the one which had been pruned. But the fact is familiar to all intelligent woodmen.

It may be regarded as an axiom in horticulture *that the health of*

other parts of a plant is in proportion to the health of leaves. There is no real exception, and the neglect of it is the fruitful parent of failures.

Nature has given plants leaves not merely to decorate *them* or to shade *us*, but as a part of a wondrous system of life quite as perfect as that of the animal kingdom. It would be of no use for a plant to suck food out of the earth by its roots, unless there was some place provided in which such food, consisting principally of water and mucilage, could be digested, and so converted into the matter which maintains the health of the individual. The stem cannot do this; firstly, because it is a mere channel through which fluids pass; and secondly, because many plants have no visible stem, as in the instance of the Primrose; and yet in all such cases the plant feeds and must digest its food. It is to the leaves that this important office is assigned, and to enable them to execute it God has formed them with wisdom no less infinite than has been displayed in the creation of man. The leaves have veins through which their fluids pass, and cells in which they are held while digesting, myriads of little caverns through whose sides respiration is maintained, a skin to guard them from the air, and pores for carrying off perspiration. A leaf is, in fact, both a stomach and lungs; and to destroy it, is to do the same injury to a plant as would be effected in an animal by the destruction of the parts to which those names are given. Of this we may be certain, that neither taste, perfume, colour, size, nor any other property, can be given to a plant except through the assistance of the leaves; and that the more numerous these are, the larger, and the more luxuriant, so, within certain limits, will be all that a plant is capable of forming. Strip the leaves off a tree, and no more wood will appear until the leaves are restored; feed its roots in the hope of thus compensating for the loss of its leaves, and the stem will be filled indeed with watery matter, but the latter will collect in the interior until it forces its way through the bark, and runs down in putrid streams, as happens to the Mulberry-tree when it is incessantly stripped for silk-worms, and as occurs to trees whose leaves are continually destroyed by a noxious atmosphere. Strip the ripening Grapes of their green garments, and no colour or sweetness will be collected in their berries. Rob the Potato of its foliage, and you will seek in vain for nourishment in its tubers; and so of all things else. On the other hand, leave the Mulberry, the Vine, and the Potato uninjured, to the genial influence of the sun and the air, and the dews of heaven, and wood is formed in the one case, sugar and colour in the other—and flour, the staff of life, in the last: and these products will all be in exact proportion to the health and abundance of the foliage. Why then mow off the leaves of Strawberry plants in the autumn as some do?—the only effect of which must be to rob the plants of the materials out of which the fruit of the succeeding year is to be produced, and to destroy the natural protection afforded during winter by

the foliage to the tender and delicate flowers which are to spring up on the return of warm weather. Why mutilate forest-trees by barbarous summer pruning? Every leaf that is then removed would have added something to the quantity and solidity of the timber, had it been spared; and although the quantity of timber formed by the separate action of each particular leaf may be, and doubtless is, extremely small, yet it must be remembered, that, in pruning, millions of leaves are removed, and that it is by millions of minute quantities that a forest is constructed.

But although the general rule is to allow as many leaves to remain on a tree as can be kept in health, yet there are circumstances which justify their removal, and, indeed, render it necessary. For example, when a tender tree is trained to a wall, a great object with the gardener is to secure ripe wood; for unless he does this, the frost of the succeeding winter may destroy the branches, or the buds may be so imperfectly formed as to produce feeble shoots the ensuing season. To attain this object, those leaves must be removed which prevent the sun from striking upon the branches to be ripened, the effect of this being to stop the rapid growth of the branches and to consolidate their tissue, in consequence, partly, of the excessive perspiration, and partly of the rapid digestion of the sap, which is thus induced; *for the rate of digestion and perspiration in a healthy plant is in proportion to the quantity of light and heat to which it is exposed.* Hence the removal of those shoots which in summer overshadow that wood of the Peach-tree which is intended to be preserved another year, is useful; there can be no doubt, however, that as few shoots as possible should be thus removed. Another case in which the removal of leaves is justifiable occurs in the Vine. In this plant the fruit is borne near the base of lateral shoots, which will, if unchecked, go on lengthening and producing leaves to a considerable distance. Now all the food of such a lateral shoot is obtained from the main branch, which, however, is only capable of furnishing a certain quantity. If the lateral shoot is allowed to grow unchecked, it will consume its portion of food in the production of many leaves and some Grapes; and the more there is of the former, the less will be the weight of the latter. But if the shoot is stopped after having formed two leaves, all that quantity of food which would have been consumed in the production of other leaves is applied to the increase of size in the Grapes and the two leaves that are left; while, on the other hand, the general crop of leaves on the Vine will be amply sufficient to prepare those secretions which are to give flavour, colour, and sweetness to the Grapes. This will, perhaps, be better explained by the annexed diagram. Let the line *a g* represent a lateral Vine-branch, bearing fruit at *B*, and leaves at *c*, *d*, *e*, *f*. Suppose six ounces of sap are destined to support this lateral *a g*, during the summer; it is evident that, if equally distributed, each leaf and branch will

receive one ounce of sap as its proportion. But if *e, f, g*, are removed, it is obvious that the three which remain will have two ounces each, or double the supply.

Why, then, it may be asked, not remove *c* and *d* also? because, in that case, *B*, the bunch of fruit, would have the whole six ounces of sap to itself. The reason why this should not be done is this: if all the leaves on the lateral are removed there will be no force left upon it wherewith to attract from the main branch the food that belongs to it; for the power which the parts of plants possess of attracting fluid is in proportion to the amount of their perspiration. Now leaves perspire copiously, but the Grapes themselves scarcely at all: whence their gradual conversion from a substance of the texture of a leaf into a mass of pulp. In the instance of Vine-pruning, the great object is to leave on the laterals just as much force as may be required to secure for the bunches the food that is intended for them, and at the same time to deprive the laterals of the means of expending that food uselessly in the production of leaves instead of fruit.

Notwithstanding the unquestionable importance of leaves to plants, yet a class of facts is familiar to practical physiologists which seems to point to an opposite conclusion. Twenty years ago Dutrochet brought to notice the unexpected fact that in the Jura may be found the roots of Fir-trees, still alive and growing, at the end of forty-five years after the trunks were felled. A similar example is recorded by the Rev. Mr. Berkeley in the case of an Ash-tree which had been sawn over level with the ground. Gardeners know very well that the tuberous Tropæolums, the stems of which have been accidentally broken off, will continue to grow for a long time afterwards; as also will tuberous Bindweeds. It chanced that in the Conservatory of Chiswick House a plant of Sello's Ipomœa was in November, 1840, destroyed to the ground by frost, *from which period to* 1852 *it had neither made buds nor leaves.* Nevertheless, its root continued increasing rapidly in size. In fact it was frequently repotted as its increase in size demanded it; for in 1840, at the time of the accident, it was but a small root. During this long period it was subjected to a high temperature. At last the root formed a coil, one foot across, six inches deep, and weighing seven pounds and a quarter. We have no record of

its weight at the time when the stem perished, but as it continued to grow for nine years and a half, and was originally in a small pot, it is not unreasonable to assume that it had acquired at least seven times its original weight. Although no leaves had been formed, yet many attempts at the production of stems were visible upon the specimen, in the form of short stunted tubercles or incipient branches; and the root was in 1852 full of vitality. Here we have a striking proof that plants may possess an inherent power of growth without leaves. It is probable that in this case the bark, of which a large surface had been exposed to light, acted as a substitute for foliage, perspiring, and assimilating food, as all green parts do, whether leaves or not. It is also possible that the surface of the root which rested upon the earth, had constantly attracted from the soil the food which the bark is assumed to have assimilated. But if such a power can be recognised in an Ipomœa, we must also admit its existence in the tuber of a Potato, even although that tuber is not exposed to light; and the vital force of the latter must be allowed to be capable not only of converting into starch the gum supplied by the leaves, but of absorbing gaseous and fluid matters from the soil, and, by their assimilation, of continuing to grow, although perhaps for only a limited time.

M. Durand, of Caen, arrived at similar conclusions. In some experiments published in the *Comptes Rendus*, Aug. 16, 1852, it was found that Poplars, Apple-trees, Acacias, &c., on which nothing was left except Miselto, grew in diameter notwithstanding the loss of their green organs. The two following experiments were more especially conclusive:—Exp. 1. At a yard and a half above the soil, an old Elm-tree was cut across before winter. The tree thus mutilated was a mere fragment of trunk under whose bark some adventitious buds were collected, so as to form a bur. The wound was covered with plastic clay. As soon as the adventitious buds began to move in the spring, they were carefully removed as fast as they appeared. Nevertheless, a layer of wood was formed. In the following years the same thing happened, that is to say, in the absence of leaf-buds, leaves, or any green parts, a layer of wood was formed every year; and it was ascertained that the roots of the Elm under experiment were not accidentally grafted with the roots of other Elms, as is said to have been the case with the Fir-trees brought into notice by Dutrochet. Lime-trees

operated upon in the same manner gave the same result. Exp. 2. A ring was cut out of a Beet-root standing above ground; the incision was made between two and three inches below the crown, where the buds and leaves grew. The crown was cut off immediately below the first leaves, excepting that a rudimentary leaf-bud was saved on one side of the plant. The bud grew; the root increased in all directions. Below the bud was formed a small protuberance, which, when examined, was found to consist of five new woody layers; but those layers did not extend round the root; they went no further than the protuberance itself. Right and left of the protuberance the plant had the same number of layers of wood as it had when the experiment commenced, which was seven. Nevertheless, the diameter of the Beet-root had much increased in the parts not beneath the protuberance. Some variation was made in this experiment, but the result was the same; it was clear that bulk increased without the assistance of leaves, &c.

A most interesting practical example of this neglected fact is recorded by the Rev. J. Smith, of Lois Weedon, the soundness of whose physiology is attested by his brilliant success where he applies principles to practice.

This gentleman has recorded in the *Gardeners' Chronicle*, for 1852, p. 707, the unexpected fact that he is able to take off his Turnips, when they have become fully organized, a crop of tops, for the use of his stock; that nevertheless the roots continue to swell, and produce a second crop of foliage, to be applied like the first: so that this part of the Turnip crop is in some sort doubled. It would be unjust not to put this fact upon record in Mr. Smith's own words. "I have made the experiment this year on an acre of Swedes, which, on my usual plan of cultivation, were managed thus:—The land—a heavy clay, with a staple originally of only five or six inches—has been gradually brought, by trenching and horse-hoeing, to a pulverised state eighteen or twenty inches deep. In the autumn I buried the manure (made by cows and swine, fed on Swedes and bran, with the other usual fodder) with two or three inches of the bottom of the rows intended for my plants; and in April, over that manure, and within five or six inches of the surface, I stirred in one hundred weight of guano. The first week in May I drilled my seed, together with a sprinkling of superphosphate, in single rows five feet apart. The result was—as it always has been under the same system, pursued for several years—that at the beginning of September the leaves of the plant met across the five feet intervals, and that I am promised a yield equal, perhaps, to the measured produce of last year, which amounted to twenty-seven tons. It will be understood by those who know the constituents and the properties of clay made friable to the depth I have described, how the continuous and inexhaustible supply of moisture in such a soil saves the plant from mildew, the common result of early sowing in shallow ground, but from

which I have never suffered, even in the driest season. Now for the confirmation of your statement, that plants will increase in bulk in the absence of leaves. Early in September, when the roots had reached their state of complete organization, when the tops had grown from two and a half to three feet in height, the lower leaves generally extending five feet wide, I began to cut the tops as they were wanted about half an inch from the crown; and from that time to this the bulbs have been proved by actual measurement to continue to grow, and are throwing out, all round the crown, a fresh supply of luxuriant leaves for another feed. From this source the bulk of keep for my cattle has been enormous; and the importance of such a supply at a time when, in common seasons, the Grass begins to fail, is beyond a doubt, especially for growing stock, since it has been proved that the leaves of the Turnip contain more of the bone-making material than even the bulb itself. I claim no merit for this experiment as a novelty, for there is a report of a somewhat similar process in the *Prize Essays of the Highland Agricultural Society*, vol. iii.; the only difference being that in that instance the Swedes had been transplanted. I would add, that it is there shown, besides, that, on analysis, as compared with Swedes treated in the common way, the root only suffered in value to the extent of containing a small per centage more of water, the quantity of solid matter being displaced in the same proportion, while the quality of the food remained uninjured." The practice of cutting off the Potato haulm in order to arrest the Potato disease, one of the best remedies for the evil yet known, points to the same general fact.

It must, however, be borne in mind, that we have no warrant for supposing that roots can grow in the absence of branches and leaves, until roots have arrived at a state of complete organization. If a plant producing tubers loses its top when the tubers are young, the latter perish or cease growing; but if the tubers are considerably advanced in formation, then they will continue to grow, notwithstanding the loss of the leaves. It would seem from this undoubted fact that a considerable amount of vital force is required in order to render a plant independent of its green organs; but that it becomes independent as soon as that amount, whatever it may be, has been acquired. In the beginning the green organs, exposed to light, appear to possess exclusively the property of elaborating the aqueous and gaseous matters which they absorb, and of so forming the material out of which growth or increase of size elsewhere is provided for. This operation takes place at that

time exclusively in the cells of the green organs, the tubes and vessels of the vegetable structure being mere recipients organized by the matters so elaborated. This power of assimilation is believed to be owing to the high vitality of the cells of the green organs; but in proportion as the subterranean parts become organized their vital force increases, and at last it becomes sufficient to enable them to act independently of the leaves or green parts. If, then, at the time when a subterranean organ is cut off from communication with the leaves, its vitality is sufficiently high, its cells not only absorb water and other matters, as was the case from the beginning, but also decompose and elaborate them, in the same way as the cells of the leaves. The result of that elaboration is increase in bulk, partly arising from the distension of the cells and the consolidation of their contents, partly from the increase of the number of the cells themselves, and also from filling the last formed cells with the matter peculiar to the species. What is required in order to secure increase in bulk is the power of organization; that power depends upon the presence of a sufficient amount of vital force; therefore, when a subterranean body has gained enough vital force, it has gained all the organic capabilities which are necessary for increase of size, or growth, and is able to enlarge even though cut off from communication with green organs. It must not however be inferred that an underground organ will increase as rapidly in the absence of leaves as it will if they are present. On the contrary, in the latter case, it grows by virtue of its own vitality and that of the leaves combined; a double power is brought to bear upon its increase, and at least twice as much food in an organizable condition is presented to it for consumption. All that we are justified in asserting is, that although leaves may be gone, growth will go on—and to a much greater extent than is supposed. If, then, a root-crop is from any accident deprived of its leaves, it is by no means a necessary consequence that the crop is arrested in its growth; on the contrary, provided the defoliation does not occur till towards the end of the season, growth will go on notwithstanding.

It is to be observed that, as has already been stated, the

capability of plants to bear the action of direct light varies according to their specific nature. One species is organized to suit the atmosphere of a dense wood, into which diffuse light only will penetrate; another is planted by nature on the exposed face of a sunburnt rock, upon which the rays of a shadeless sun are daily striking: in these cases, the light which is necessary to the one would be destructive of the other. The organic difference of such species seems to consist chiefly in the epidermis, which regulates the amount of perspiration. It is therefore to be remarked, that it is not the greatest quantity of light which can be obtained that is most favourable to the healthiness of plants, but the greatest quantity they will bear without injury. If the former were true, the concentrated light of a lens would be better than the strongest ordinary light; but the effect of the concentrated light of a lens is to burn the surface, and the ordinary solar rays produce the same effect upon many plants, probably by exhausting the tissue of its water faster than it can be supplied from the roots.

In the course of time, a leaf becomes incapable of performing its functions; its passages and surface are choked up by the deposit of impurities; there is no longer a free communication between its parenchyma and that of the rind, or between its veins and the wood and liber; or the air and its interior. It changes colour, ceases to decompose carbonic acid, absorbs oxygen instead, gets into a morbid condition, and dies: it is then thrown off. This phenomenon, which we call the *fall of the leaf*, is going on the whole year round, except mid-winter, in some plant or other. Those which lose the whole of their leaves at the approach of winter, and are called deciduous, begin, in fact, to cast their leaves within a few weeks after the commencement of their vernal growth; but the mass of their foliage is not rejected till late in the season. Those, on the other hand, which are named evergreens, part with their leaves much more slowly; retain them in health at the time when the leaves of other plants are perishing; and do not cast them till a new spring has commenced, when other trees are leafing, or even later. In the latter class, the functions of the leaves are going on during all

the winter, although languidly; they are constantly attracting sap from the earth through the spongelets, and are, therefore, in a state of slow but continual winter growth. It usually happens that the perspiratory organs of these plants are less active than in deciduous species.

In general, a leaf is an organ of digestion and respiration, and nothing more; some leaves have, however, the power of forming leaf-buds, if placed in or upon the earth, under suitable circumstances.

The Bryophyllum calycinum forms buds at the indentations of its margin; Malaxis paludosa throws off young buds from its edge; Tellima grandiflora occasionally buds at the margins of its leaves; the same thing happens to many Ferns; the five leaflets of a pinnated Rose-leaf yield, under proper culture, five little plants; Cape Ornithogalums often produce bulbs from the edge of their leaves; the same fact has been observed by Mr. Rogers on the broken edge of a Lachenalia leaf; and numerous similar instances might be quoted.

CHAPTER VI.

ACTION OF FLOWERS.

STRUCTURE OF FLOWERS.—NAMES OF THEIR PARTS.—TENDENCY OF THE PARTS TO ALTER AND CHANGE INTO EACH OTHER, AND INTO LEAVES. —DOUBLE FLOWERS.—ANALOGY OF FLOWERS TO BRANCHES.—CAUSE OF THE PRODUCTION OF FLOWERS.—OF PRODUCTIVENESS.—OF STERILITY. —USES OF THE PARTS OF A FLOWER.—FERTILISATION.—HYBRIDS.— CROSSBREDS.

A FLOWER is that part of a plant which is formed for the purpose of reproducing the species by means of seeds. It consists of floral envelopes and sexes.

The floral envelopes are: 1, the calyx, which is usually green, and always the most external; and 2, the corolla, which is commonly thin, gaily coloured, more fugitive than the calyx, and placed next within it: each of these consists of leaves, called sepals in the calyx, and petals in the corolla. Both calyx and corolla are usually present; but in some cases only one envelope is formed, as in the Marvel of Peru; and in other cases the flower has no envelopes, as in the Willow. Envelopes are, therefore, not a necessary part of a flower.

In the middle of the flower stand the sexes, called stamens and pistil, of which the pistil occupies the centre, and the stamens surround it; except in those cases where the sexes are produced in separate flowers, when each sex is central in its own flower. The stamens consist of a filament and an anther, in the interior of the latter of which is secreted a powdery substance termed pollen. The pistil consists of ovary, style, and stigma, in the interior of the first of which are ovules or young seeds.

Although the floral envelopes may be, and often are, absent,

wholly or in part, yet the sexes are always present. Consequently the latter are all that is essential to a flower, and no part can be a flower from which they are absent.

Notwithstanding the difference in form and office of the parts of a flower, they have evidently a strong tendency in cultivated plants to change into or assume the appearance of each other. In the Poppy, the Garden Anemone, and many others, the

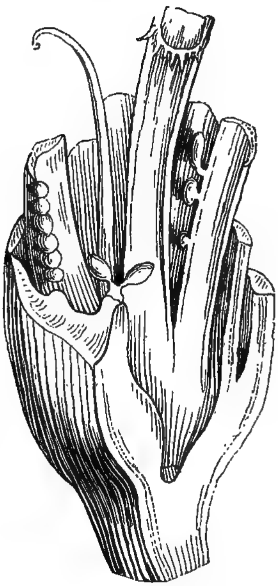


Fig. XV.—Transformation of organs in an Amaryllis.

stamens change into petals; in the Anemone, the Ranunculus, &c., the pistil changes into petals; in the Primrose, Cowslip, &c., the calyx changes into petals; in the Houseleek, the stamens become pistils; and so on. Hence the origin of double flowers. In a double Barbadoes Lily, described by me in the *Transactions of the Horticultural Society*, in which the parts were very much confused, the young seeds were borne by the edges of the stamen-like petals (Fig. XV.).

In their ordinary state the parts of a flower are extremely unlike leaves, and each has its allotted office, which is not the

office of a leaf; they are also incapable of forming leaf-buds in their axils. But, although such is the case, there is found a strong and general tendency on the parts of both the floral envelopes and sexes to change to leaves, similar to the leaves of the stem.

Fig. XVI.—Transformation of Clover.

In the white clover (Trifolium repens, Fig. XVI.) all the parts often become leaves; in the Fraxinella (Fig. XVII.) this has also been

Fig. XVII.—Transformation of Fraxinella.

remarked.* Partial alterations into leaves are in fact of very frequent occurrence in the parts of a flower. In the Rose, the sepals and pistil

* *Proceedings of the Horticultural Society*, vol. i. p. 37.

are frequently changed into leaves, of which the case represented in the following cut (Fig. XVIII.) is a most striking example. In this case the

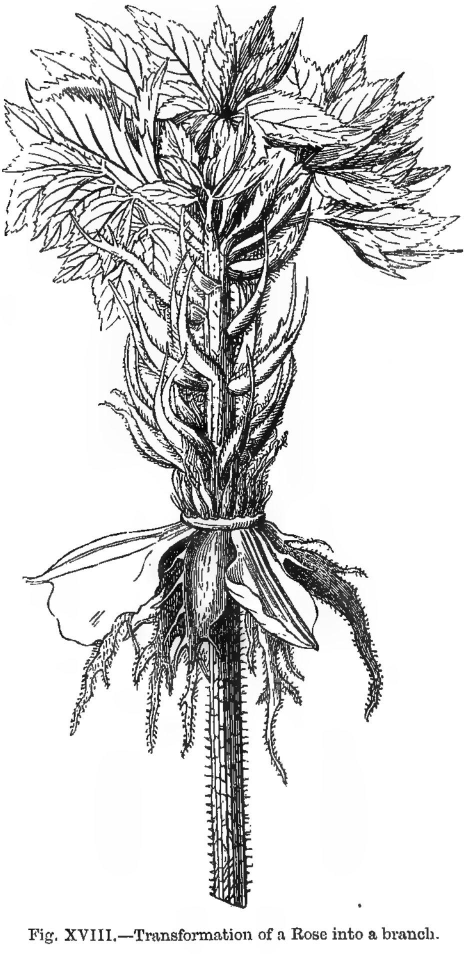


Fig. XVIII.—Transformation of a Rose into a branch.

calyx-tube was absorbed or not developed; the sepals were half converted into leaves; the petals were more than half changed into sepals; the outer carpels were partly in their customary state, those nearer the centre were converted into small leaves, and the remainder were carried up upon the axis or centre, which had lengthened into a branch in every conceivable state of transition, until the last-formed, namely, the

uppermost, assumed the usual appearance of the leaves of the stem. (See *Gardeners' Chronicle*, 1847, p. 171, for this and similar facts.) In the Double Cherry, the pistil is almost always to be found in the form of a leaf; and books on structural botany abound in the records of similar cases. It sometimes happens that buds are not only formed, but developed, at the axils of the parts of a flower, as in a Celastrus

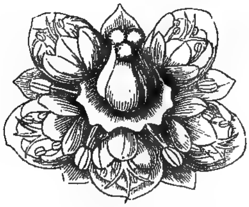


Fig. XIX.—Transformation of Celastrus.

scandens observed by Kunth (Fig. XIX.). Rose-buds are frequently seen growing out of Roses. A very striking and uncommon accident was observed by the late Mr. Knight in the Potato (Fig. XX.), whose

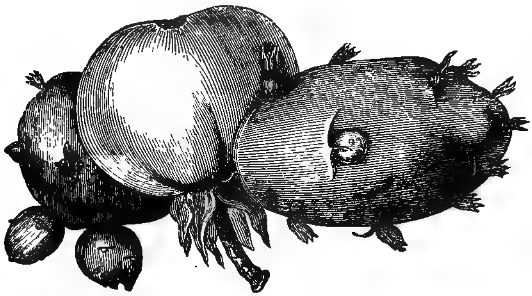


Fig. XX.—Tubers produced in the axils of sepals and petals.

flowers produced young potatoes in the axils of the sepals and petals.* Occasionally, the centre of a flower lengthens and bears its parts upon its sides, as in the Pear and Apple, whose fruit is often found in the state of a short branch. Still more rarely a flower lengthens, and produces from the axils of its parts other flowers arranged over its sides, as in the Double Pine-apple of the Indian Archipelago.

* *Proceedings of the Horticultural Society*, vol. i. p. 39, fig. 2.

The following cuts represent three Pears, produced in different places, and in different conditions. A Pear blossom consists of a calyx composed of five sepals; within these appear five petals, next to which stand about twenty stamens; and in the centre of all are five carpels, or hollow cases, arranged in a ring, and containing seeds. All these parts are regarded in theory as leaves in an altered state, and the whole flower as a very short branch, destitute of the usual power of lengthening, or, which is the same thing, as a leaf-bud, the centre of which will not extend. In the beginning the sepals, petals, stamens and carpels of a Pear flower were scales, placed upon a fleshy centre, and not distinguishable from those scales which in the leaf-bud become leaves. To use a gardener's language, there was at first no difference between the blossom-bud and the wood-bud. But, after a time, the parts which were identical begin to be organized differently; in the blossom-bud they gradually change into sepals, petals, stamens, and carpels; in the wood-bud they become young leaves. But if anything occurs to disturb the development of the blossom-bud as a blossom, then it becomes a wood-bud, or approaches that state, more or less, according to the period at which the disturbing force began to act. It thus appears that whether a bud becomes a flower or a branch, depends entirely upon some unknown force, which acts at a particular moment upon parts originally of identical nature and quality, and capable of becoming leaves; if this action is complete, a flower is the result; if incomplete, a monster; if altogether withheld, then the rudimentary parts, not having their nature changed, proceed to acquire the condition of leaves. Hence it is that when from accidents, such as unusual heat and wet at a critical moment, exuberance caused by the excessive application of rank (azotized) manure, or any circumstances of a similar nature, the usual order of development is disturbed, flowers are not formed—or we have them converted into tufts of leaves, or even branches. The following examples offer conclusive evidence as to the truth of this theory:—

Fig. XXI. represents a Pear, in which the calyx and its five sepals are not much disturbed, but in which the petals and

part of the stamens, developed in the form of leafy scales, adhere round the centre of the flower, which has lengthened somewhat like a branch, while the remainder of the stamens and the carpels are concealed within the summit, in the form of withered rudiments. The constitutional tendency to fleshiness, which is the characteristic of the Pear, is not lost, in this or either of the two other cases, but is preserved throughout, only diminishing towards the eye.

Fig. XXI. Transformed Pears. Fig. XXII.

In Fig. XXII. the phenomena take a somewhat different direction, the leafy tendency being greater in some of the sepals, but the tendency to acquire succulence having been preserved in a far greater degree; as if the disturbing cause, whatever it may have been, which originally prevented the young parts from becoming petals, &c., and which forced the centre to lengthen like a branch, was effectually withdrawn and overcome by the tendency to become succulent, which the parts had already acquired, when the disturbing cause began to act.

In Fig. XXIII. the change advances further, and in another direction. That dislocation of the rings of parts belonging to the flower, which was so visible in the two last cases, is here carried still further; and, in addition, two of the young parts near the middle of the whole structure have each formed in

Fig. XXIII.—Transformed Pear.

their axil one bud, which has become a deformed flower, and produced a deformed Pear. No organ of the plant, except leaves and their modifications, has the power of producing a flower from its axil.

The following additional illustrations of these facts may be mentioned:—Fig. XXIV. represents a branch of a Pear in which one flower (*a*) is in a deformed state, but still sufficiently recognisable, and another completely changed into a branch; the calyx assuming the appearance of leaves or leafy scales (*s s*), the petals also partially transformed into leaves (*p p*), while the whole apparatus of stamens and pistils is converted into an

Fig. XXIV.—Transformed branch of Pear-tree.

ordinary branch. Fig. XXV. shows the state of plants of Potentilla nepalensis with their flowers changing to branches: *a* is a flower in the ordinary condition; at *b* it is partly changed in a slight degree; at *c* all the sepals, petals, and stamens are converted into leaves, but the pistils are little changed; at *d* the sepals, petals, and stamens are but little

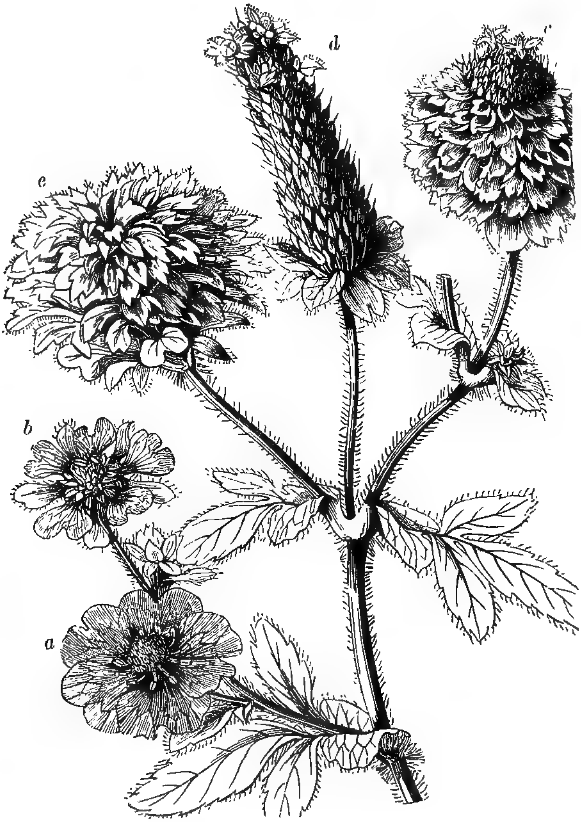


Fig. XXV.—Transformed Potentilla.

altered, but the receptacle of the fruit is lengthening into a branch, and is covered by the carpels partly converted into leaves, and some of them near the apex producing flowers from their axils; finally, at *e*, the whole of the floral apparatus is changed into a rosette of leaves. A monstrous Foxglove has been seen to present analogous appearances.

Of such a case, Fig. XXVI. is a representation of the natural size. Its structure was as follows:—Firstly, a calyx, consisting of 12 sepals, distinct to the base. Secondly, a corolla as large as the Hebe's Cup Rose, lobed with considerable irregularity; deep rich rose, with the peculiar ocellated spots of Digitalis. Near its base were 12 perfect stamens. Thirdly, another calyx, regular, cup-shaped, with 13 short triangular teeth. Fourthly, within this a second corolla, paler, with

Fig. XXVI.—Transformed Foxglove.

purple not ocellated spots, almost hemispherical, very irregularly lobed, in three irregular whorls, with 11 stamens in a more or less monstrous state. Fifthly, in the midst, a lengthened axis covered with numerous leafy, petal-like or stamen-like lobes, forming a confused tuft. No pistil; but all sorts of transitions from stamens to scales and leaves. This further evidence assists in proving not only that a flower is a branch, but that irregular flowers will occasionally become regular; and that, becoming so, they make up for all the deficiencies and peculiarities of the ordinary structure, by taking on the customary state of regular flowers; that all the parts of a flower are leaves in various states of development; and that the axis of a flower is a growing point, capable of indefinite extension as soon as the forces which determine the production of a flower are disturbed.

It is therefore clear that although the parts of a flower are different both in appearance and office from leaves, yet they do

all assume, under particular circumstances, the same appearance and office. Hence it is inferred that they are really nothing more than leaves in a modified state; and, consequently, that a flower is a very short branch, and a flower-bud analogous in many respects to a leaf-bud. A leaf-bud is a collection of leaf-scales of the same or similar form, arranged round a central very short branch, having a growing point. A flower-bud is a collection of leaf-scales of different forms, arranged round a central very short branch, not having a growing point under ordinary circumstances. In this latter respect it resembles those buds of the Larch which form leaves in starry clusters, without extending into a branch. Many points in horticulture could not be explained until the existence of this analogy was made out.*

What it is that causes a plant to convert some of its buds into flowers, by fashioning the leaves into calyx, corolla, stamens, and pistils, while other buds become branches clothed with ordinary leaves, is beyond the reach of explanation. There are, however, certain facts connected with it which require notice. It is clear that plants begin to fructify at some determinate period, varying in different species. In annuals this occurs in a few weeks or months after germination;

* This doctrine has been taught at different times, by different independent observers. Among other persons, I find that Mr. Knight had come to the same conclusion, at a time when the views of Wolffius and Goethe were quite unknown in England. He says: "The buds of fruit-trees which produce blossoms, and those which afford leaves only, in the spring, do not at all differ from each other, in their first stage of organization, as buds. Each contain the rudiment of leaves only, which are subsequently transformed into the component parts of the blossom and in some species of the fruit also. I have repeatedly ascertained that a blossom of a Pear or Apple-tree contains parts which previously existed as the rudiments of five leaves, the points of which subsequently form the five segments of the calyx; and I have often succeeded in obtaining every gradation of monstrosity of form, from five congregated leaves (that is, five leaves united circularly upon an imperfect fruit-stalk), to the perfect blossom of the Pear-tree. The calyx of the Rose, in some varieties, presents nearly the perfect leaves of the plant, and the large and long leaves of the Medlar appear to account for the length of the segments, in the empalement of its blossom. The calyx of the blossom of the Plum and Peach-tree is formed precisely as in the preceding cases, except that the leaves which are transmuted into the calyx separate at the base of the fruit, and become deciduous, instead of passing through and remaining a component part of it." (*Transactions of the Horticultural Society*, vol ii. p. 364. May 6, 1817.)

in biennials a longer period is required before this condition is arrived at; and in shrubs and trees a still greater age must be acquired. The American Aloe will not flower before it is thirty years old, under the most favourable conditions; and, under unfavourable circumstances, the age at which it fructifies is so much increased as to have given rise to the vulgar belief that it flowers only after a hundred years. This curious subject has been little investigated, and we have no comparative statements of the ages at which different species begin to bear; but the fact is certain. It is often, however, in the power of man to advance or retard these periods artificially. Whatever produces excessive vigour in plants is favourable to the formation of leaf-buds, and unfavourable to the production of flower-buds; while, on the other hand, such circumstances as tend to diminish luxuriance, and to check rapid vegetation, without affecting the health of the individual, are more favourable to the production of flower-buds than of leaf-buds. Thus, a plant in a sterile soil and exposed situation flowers sooner and more abundantly than one in a rich and shaded place; young vigorous plants flower later and less abundantly than old ones. In India and China fruit-trees are made to bear by cutting their roots, or exposing them periodically to dryness; and in this country the same practice is observed, especially with the Fig tree. An apparent exception to this law is found in the fact that a seedling fruit-tree may be made, by grafting upon an old stock, to bear flowers at an earlier age than it otherwise would have done; for the effect of grafting it thus is certainly not to render it less vigorous, but the contrary. But it is probable that all these facts arise out of one common law, which is, that the period when a plant begins to flower depends upon the presence in its system of a sufficient quantity of secreted matter fit for the maintenance of the flowers when produced. Under ordinary circumstances, a considerable part of all the nutritious secretions elaborated by the leaves are expended in the production of new leaves; but after a time, a greater supply is formed than the leaves require, and the residue collects in the system; as soon as this residue has arrived at the necessary amount, flowers may begin to form. If the sterile branch

of a tree is ringed,* it ceases to be sterile; and this can only be accounted for upon the supposition that the secreted matter of the branch, instead of being conveyed away into the trunk and roots, is stopped by the annular incision, above which it is compelled to accumulate. If a tree that is unproductive be transplanted, it begins to bear; in this case the operation injures its roots, sap is therefore less abundantly supplied in the succeeding season to the leaves; the leaves are therefore less able to grow than they previously were, and they consequently do not consume the nutritious matter lying in the branches, and which they would have expended, had they been able to grow with their former vigour; hence the nutritious matter accumulates, and flower-buds are formed. In this country, if a fruit-tree has its crop destroyed one year, it bears the more abundantly the next; owing, no doubt, to the accumulation in its system of that nutritive matter which would not have been present there, had the crop which was destroyed been allowed to grow: and the reverse of this is well known to be the fact; an excessive crop one year being followed by a scanty crop the succeeding year. So, when a young seedling fruit-tree is made to bear prematurely by grafting it upon an old stock, the effect of which will apparently not be to diminish its vigour, it may be conceived that, in the first place, the seedling will receive a considerable quantity of nutritive matter from the old stock, where it had been already collected, and that thus the supply will be greater than the consumption, however large the latter may be; and, secondly, that, at the time of union of itself with the stock, there will be sufficient interruption of continuity in the bark to oppose some obstacle to the descent from the seedling of whatever matter it may have received or

* One of the effects of ringing has been observed to consist in the formation of numerous barren shoots below the wound, while fertile shoots appear above it. This is conformable to the theory of the formation of flowers being determined by a superabundance of nutritious matter in a given place. The bark below the annular excision is cut off from a supply of the sap elaborated by the leaves above it; and, at the same time, in consequence of the obstruction of the wound to the ascent of the crude sap, an unusual supply of the latter is forced towards the buds in the bark below the wound, which buds, being chiefly fed with crude sap, push forth into branches and leaves, but bear no flowers.

formed. Hence, it is an axiom in vegetable physiology, that the production of flower-buds depends upon the presence of nutritive matter in sufficient abundance for their support.

The use of the calyx and corolla is too uncertain and unimportant to demand much notice. The calyx is usually regarded as a protecting organ, and the corolla as a part for the embellishment of the sexes. They neither appear to be of much physiological importance; more especially not the corolla, or it would not be absent in such large numbers of plants.

The use of the stamens is to effect the fertilisation of the young seed contained in the pistil. To this end, the pollen of the anther must be applied to the stigma, the result of which is, that an embryo, the rudiment of a future plant, is generated in the inside of the young seed, and, when mature, is capable of multiplying the species. It is, however, to be observed, that the seed, when ripe, will not renew the species from which it is derived, with all its individual peculiarities; the seed of a Green Gage Plum, for instance, will not, with any certainty, produce a plant having the sweet green fruit of that variety, but it may produce a Plum whose fruit is red and acid. All that the seed will certainly do is to produce a new individual of the Plum species: the peculiarities of individuals are perpetuated by other means, and especially by leaf-buds. (See Book II.)

It has been remarked that the freshness of flowers may be much prolonged by any circumstance which hinders the act of fertilisation. Orchidaceous plants in hothouses are an instance of this. In general, from the absence of insects, or of those other disturbing causes to which Orchidaceæ are exposed in their native places, the pollen cannot come into contact with the stigma, and so long as this is prevented the flowers of many species will retain their freshness for weeks, as if in expectation of that event for which they were created. But as soon as the act of fecundation is accomplished, that is to say, from twelve to twenty-four hours after the pollen touches the stigma, the flowers collapse, the bright colours become dim, the ovary begins to enlarge, and the beauty of the flower is gone. The same fact has been noticed in the Night Flowering Cereus, whose flowers will retain their beauty during the day after blossoming, provided the stigma is removed.

If the pistil of one species be fertilised by the pollen of another species, which may take place in the same genus, or if

two distinct varieties of the same species be in like manner intermixed, the seed which results from the operation will be intermediate between its parents, partaking of the qualities of both father and mother. In the first case the progeny is *hybrid*, or mule; in the second it is simply *crossbred.*

In general, crossbreds are capable of producing fertile seed, and thus of perpetuating one of the species from which they sprang. Hybrids, on the contrary, are often sterile, and therefore incapable of yielding seed.

Reasoning from a few facts, and from the analogy of the higher orders in the animal kingdom, it has been believed that all vegetable hybrids are sterile; and, when sterility is not the consequence of the intermixture of two species, it has been thought that such species are not naturally distinct, however different their appearance. But facts prove that undoubted hybrids *may* be fertile; and when we consider that plants are not analogous to the higher orders of animals, but to the lowest, concerning whose habits we know little, it is obvious that no analogical inferences can be safely established.

CHAPTER VII.

OF THE MATURATION OF THE FRUIT.

CHANGES IT UNDERGOES.—IS FED BY BRANCHES UPON ORGANIZABLE MATTER FURNISHED BY LEAVES.—PHYSIOLOGICAL USE OF THE FRUIT.—NATURE OF SECRETIONS.—THE CHANGES THEY UNDERGO.—EFFECT OF HEAT.—OF SUNLIGHT.—OF WATER.—SEEDS.—ORIGIN OF THEIR FOOD.—CAUSE OF THEIR LONGEVITY.—OF THEIR DESTRUCTION.—DIFFERENCE IN THEIR VIGOUR.

After the fertilization of the seed has taken effect, the pistil by itself, or the pistil and surrounding parts, go on growing; alter their appearance, as well as size; acquire new qualities of colour, texture, flavour, &c.; and become the fruit.

A flower being a kind of branch, as has been already shown (see page 83), and the fruit being the advanced stage of a flower, it follows that a fruit is also a kind of branch. It has originally the same organic connexion with the plant as other branches, and like them requires to be supplied with food, in the absence of which it perishes or languishes.

It may be conceived that, as the fruit is an altered state of a leaf, its physiological action will resemble that of a leaf, in proportion as it retains its organic similitude; and this is found to happen, a fruit decomposing carbonic acid, &c., under the influence of light, so long as it retains its original green foliaceous character. In the Pea, for example, whose pod is green until it begins to die, the action is always similar to that of a leaf, but in the Peach, whose texture becomes pulpy and unlike that of a leaf, the physiological action eventually ceases to be that of the latter organ.

But although a fruit has, like a leaf, the power of forming secretions by elaborating the sap which is attracted into it, yet

because of its smallness, the amount of this power is inconsiderable: it contributes little to the general secretions of the plant that bears it, depends for its nutriment upon the neighbouring leaves, and expends its powers in the elaboration of matter for its own use. That it does, however, form wood, like ordinary leaves, is evident, if the flower-stalk of a Cherry is compared with the stalk of the fruit of the same tree; and this becomes still more apparent when the elaborating forces of many separate fruits are, in consequence of their compact arrangement, brought to contribute to the lignification of a common stalk, as in the Pinaster tree.

The exhausting action of fruit is well illustrated by the well known fact, that when plants cultivated for the sake of their flowers only, are permitted to ripen their fruit, the power of flowering in a succeeding season is diminished. This is seen in Rhododendrons, and Azaleas. When the Rhododendron goes out of flower, it forms clusters of seed-vessels, which swell during the summer, and by the autumn become ripe, whether the seeds they contain are good or not. In their mature state they are of considerable size; and they arrive at it by feeding upon the organizable matter formed in branches during summer by the leaves. This organizable matter, if not consumed by the seed-vessels, is stored up and applied to the formation of flowers: if it is consumed in the creation of fruit it is abstracted from whatever means the plant may have of generating flowers. It is, therefore, obvious that to prevent the formation of fruit is to promote the future production of flowers, and, acting upon this principle, all good gardeners break off the young Rhododendron fruit, as soon as the flowers have fallen. The same rule applies to all other cases.

The great purpose for which the fruit is formed seems to be the protection and nutrition of the seed, the perfect maturation of which is essential to the perpetuation of the races of plants. In most cases the whole of the fluid or nutritious parts is consumed in effecting this end; but in certain instances there is a surplus, which, if sweet, and unmixed with deleterious secretions, becomes fit for food. In either case, the fruit has, in common with leaves, the power of attracting food from the

surrounding parts; and we see that this property causes the destruction of some fruits by their neighbours which are more advanced in growth, or accidentally more vigorous, and whose attracting power is so great as to draw to themselves all the food intended for the weaker fruits, which then fall off. Of the food thus to be consumed in the maturation of the fruit, a portion is derived from the atmosphere, but the principal part has to be prepared by the leaves, which obtain it in a great measure from the earth through the roots. It is, therefore, evident, that all causes, of whatever nature, which interfere with the healthy and regular action of the leaves and roots will also interfere with the fruit. Or, if the leaves are placed in such a manner with respect to the fruit, or at so great a distance from it, that the fruit is unable to attract food from them, it must either suffer or perish. This explains why fruit formed upon naked branches will not continue to grow, and why the presence of a leaf immediately above a fruit, on the same branch, is so beneficial to it. The size and excellence of fruit will hence be in proportion to the abundance of organizable matter prepared and stored up in its vicinity.*

It occasionally happens that stone-fruit will swell upon naked branches; but such cases are exceptional, and probably depend upon circumstances unrecorded by those who have observed them. It has been admitted that, in some instances, such fruit has been altogether deficient in flavour; though in others it is said to have been otherwise. See the *Gardener's Chronicle* for 1842, p. 588, and for 1843, pp. 43 and 115.

* The accumulation of sap, and its consequent viscidity, may, however, be attended with disadvantage to a plant, as really happens in the Potato, the most farinaceous varieties of which are liable to a disease called the "curl." Mr. Knight attributed this to the inspissated state of the sap, which, he conceived, if not sufficiently fluid, might stagnate in and close the fine vessels of the leaf during its growth and extension, and thus occasion the irregular contractions which constitute this disease. He therefore suffered a quantity of Potatoes, the produce almost wholly of diseased plants, to remain in the heap, where they had been preserved during winter, till each tuber had emitted shoots of three or four inches in length. These were then carefully detached, with their fibrous roots, from the tubers, and were committed to the soil, when, having little to subsist upon except water, not a single curled leaf was produced, though more than nine-tenths of the plants which these identical tubers subsequently produced were much diseased. The same effect has been produced by other persons, by taking up the tubers intended for seed before they were full grown, and, consequently, before the excessive inspissation of their secretions had taken place.

Although fruit has, in common with leaves, the property of elaborating the sap, yet there is this difference between them; that, while leaves return back into the stem what matters they form, fruit retains the principal part of what it secretes for the use of itself or of the seeds it contains. This difference is probably to a considerable extent dependent upon the imperfect condition of the fruit-stalk, which has little power of carrying off from the fruit the matter which is formed within it. In those cases, however, in which the fruit has stomates, the aqueous particles are given off through the sur face of the fruit which then becomes hard or dry when ripe; but in others, in which there are no stomates, or few, or imperfect ones, aqueous particles cannot be extricated to any considerable amount, and the fruit becomes succulent.

The maturation of the fruit is dependent, then, upon the action of the leaves and roots, and the secretions that it forms are principally derived from the former. Consequently, whatever contributes to the healthy condition of the leaves and roots will have a directly beneficial influence upon the fruit, and vice versâ. It is, however, certain, that the juices furnished by the leaves undergo a further alteration by the vital forces of the fruit itself, which alteration varies according to species. Thus the fruit of the Peach is sweet, but there is no perceptible sweetness in its leaves; and the fruit of the Fig is bland and wholesome while the leaves of that plant are acrid and deleterious.

Among the immediate causes of the changes that occur in the secretions of fruit are heat and light; without which the peculiar qualities of fruits are imperfectly formed, especially in species that are natives of countries enjoying a high summer temperature. It is found that among the effects of a high temperature and an exposure to bright light is the production of sugar and of certain flavours; and that under opposite circumstances, acidity prevails.

In this respect, fruit only obeys the general laws which regulate the formation of vegetable secretions. Heat and light are unquestionably the agents, though perhaps not the sole agents, upon which all the qualities of plants depend. For

example, the Œnanthe crocata, whose leaves and roots are poisonous in the midland counties of England, is innoxious in the lower temperature and cloudier sky of Edinburgh; no art can induce the Rhubarb plant to form in Europe the medicinal substances which give value to the drug in those bright, and heated regions of Asia which it inhabits; nor can the Tomatoes or Aubergines ripened in England be for a moment compared for excellence to those produced in the North of Africa.

It must however be observed, that the effect of heat and light is greatly increased by free exposure to currents of air, such as are incessantly acting upon the surface of plants in the open ground. Whether this results from the greater abstraction of moisture, or from a more abundant supply of gaseous food to be absorbed from the atmosphere, or from any unknown circumstance, it is certain that all vegetable secretions, of whatever kind, are improved in quality when air has the fullest access to the plants. Of this we have abundant proof when we contrast the pallid, subacid Pine-apples of forcing houses, with those ripened out of doors as has been practised in the garden of the Baroness Rolfe at Bicton; or when we compare the brilliant colours and rich perfume of flowers and fruit formed in thoroughly ventilated hothouses, with the same productions taken from glass houses to which the air has very little access.

The following is the manner in which the Pine-apples above alluded to were grown at Bicton.

In May Mr. Barnes, having some plants ready, opened a trench, casting the earth right and left, so as to form a bank on each side, which would afford shelter from cold winds; in the bottom of the trench he placed bricks in threes, in the form of a triangle, so as to make a dry bottom for the plants to stand on, and at the same time to secure a ready passage for air and water. The plants having been placed on the bricks, were packed to the rims of the pots in leaves which had been used during the winter. This being done, the whole surface, banks and all, was covered with *charred* hay or grass, for the purpose of absorbing heat, retaining it, and giving it off gradually. Although the weather proved cold, with frosty mornings, and many sunless days, yet no injury was sustained, and when the sun did appear the fruit made great progress; at the same time the suckers which sprung up grew vigorously and were most healthy. The varieties employed consisted

chiefly of Queens, Black Jamaica, Montserrat, Enville, Moscow Queen, Anson's Queen or Otaheite, and Black Antigua. The plants employed had never been subjected to fire heat at any time. They were turned out after they had blossomed. The fruit, ripened under these circumstances, was of the highest quality in point of flavour; and although the night temperature to which the plants were exposed, was occasionally below 40°, no injury was sustained by them. The cold winds were kept off by banks thrown up across the prevailing currents. The want of a sufficient amount of earth heat was compensated for by a "lining" of leaves still capable of fermentation. And by covering the scene of the experiment with a black substance, the heat-absorbing power of the ground was so much increased as to enable it to maintain a night atmosphere round the plants high enough to repel the late frosts of Devonshire, and to maintain a healthy growth during the day.

The admirable flavour of the fruit could not have been owing to high temperature, nor to bright and long-continued sunshine, for the weather was stormy, with many dark sunless days. It was caused by the free access of air constantly passing over the leaves, incessantly feeding them on the one hand, and helping them on the other to elaborate their juices by the as incessant removal of their superfluous water. The fruit was not indeed very large, but its size was as great as sufficed to render it an ornament to a table, as the following weights of fruit cut in 1847 prove.

July	7—2	Queens, whose	united weights	were	8 lbs.	6 oz.
	18—1	,,	,,	,,	4	0
	28—1	,,	,,	,,	4	8
Aug.	11—1	,,	,,	,,	4	0
	14—1	,,	,,	,,	4	7
	21—1	Enville	,,	,,	6	2
	24—1	Queen	,,	,,	4	8
	31—1	,,	,,	,,	4	8
Sept.	26—1	Enville	,,	,,	6	0
Oct.	4—1	Montserrat	,,	,,	4	8
	9—1	,,	,,	,,	5	0
		Total .	.	. .	55 lbs.	15 oz.

Others, cut at intervals, weighed from 3 lbs. 8 oz. to 4 lbs.

One of the most essential of the alterations which occur in fruits during ripening is the decomposition or dissipation of the water that they attract from the stem. A diminished supply of water will, under equal circumstances, produce an accelerated maturation, because less time will be required to decompose

or dissipate this constituent; and, on the other hand, an excessive supply of water will retard or prevent ripening, in consequence of the longer time required for the same purpose.

Seeds are affected by all circumstances that affect the fruit, which, indeed, as has been already stated, appears to be created for their nutrition and preservation. In general, the fruit attracts organizable matter from the stem through the stalk, and the seed from the fruit through its placenta; * and this accounts, independently of other causes, for the importance of the fruit to the seed.

When the seed is ripe it is dry, all its free water being parted with; and its interior is occupied by starch or fixed oil, or some other such substance, together with earthy matters. It would seem that, so long as these secretions remain undecomposed, so long does the vitality of the seed continue unimpaired; and hence the great age at which certain kinds of seeds have been found to grow. But, as it is difficult to prevent their decomposition, so is it difficult to preserve seminal vitality for any considerable time; and the differences found in the duration of the growing powers of seeds probably depend principally upon differences in their chemical constitution. Oily seeds, which readily decompose, are among the most perishable; starchy seeds, which are least subject to change, are the most tenacious of life.

Not to speak of the doubtful instances of seeds taken from the Pyramids having germinated, Melons have been known to grow at the age of forty years, Kidneybeans at a hundred, Sensitive-Plant at sixty, Rye at forty; and there are now living, in the garden of the Horticultural Society, Raspberry plants raised from seeds sixteen-hundred or seventeen-hundred years old. The seeds of Charlock buried in former ages spring up in railway cuttings; where ancient forests are destroyed, plants appear which had never been seen before, but whose seeds have been buried in the ground; when some land was recovered from the Baltic sea, a Carex was found upon it, now unknown in that part of Europe. M. Fries, of Upsala, succeeded in growing a

* The placenta is a soft part of the interior of a fruit, upon which the seed is formed. It is composed of thin-sided parenchyma, the most absorbent of all the forms of tissue, and is in communication, by its whole surface, with the parenchyma of the fruit.

species of Hieracium from seeds which had been in his herbarium upwards of fifty years. Desmoulins has recorded an instance of the opening of ancient tombs, in which seeds were found, and on being planted they produced species of Scabiosa and Heliotropium. And many more such cases are on record, establishing conclusively that, under favourable conditions, the vitality of seeds is preserved for indefinite periods.

Warmth, moisture, and an excess of oxygen, but especially warmth and moisture, while they are the greatest causes of germination, are probably, on that same account, the chief causes of death. It seems as if seeds remain dormant so long as the proportion of carbon peculiar to them is undiminished; water is decomposed by their vital force; and it is believed that its oxygen, combining with the carbon, forms carbonic acid, which is given off. The effect of access of water is, therefore, to rob seeds of their carbon; and the effect of destroying their carbon is to deprive them of the principal means which they possess of preserving their vitality.

Be this as it may, it is incontestable that as soon as seeds begin to germinate, their vitality is exhausted and they perish, unless the seed is in a condition to continue its growth by obtaining sufficient food from surrounding media.

Although a seed, if fully formed, is in all cases capable of perpetuating its race, yet there is a difference in the degree to which this capability extends. All seeds will not equally produce vigorous seedlings: but the healthiness of the new plant will correspond with that of the seed from which it sprang. For this reason, it is not sufficient to sow a seed to obtain a given plant: but, in all cases where any importance is attached to the result, the plumpest and heaviest seeds should be selected, if the greatest vigour is required in the seedling; and feeble or less perfectly formed seeds, when it is desirable to check natural luxuriance. It is apparently for this reason, that old Melon seed is preferred to new; for the latter would give birth to plants too luxuriant for the small space in which the Melon can be cultivated, under the artificial circumstances required in this country.

Since both fruit and seeds are maintained at the expense of the leaves, the destruction of the former, when young, will enable the latter to deposit against a succeeding season, for the support of future flowers, all that organizable matter which the fruits and seeds destroyed would have otherwise consumed.

CHAPTER VIII.

OF TEMPERATURE.

LIMITS OF TEMPERATURE ENDURABLE BY PLANTS.—EFFECTS OF A TOO HIGH TEMPERATURE.—OF A TOO LOW TEMPERATURE.—FROST.—ALTERNATIONS OF TEMPERATURE.—DAY AND NIGHT.—WINTER AND SUMMER.—TEMPERATURE OF EARTH AND ATMOSPHERE.

THE extreme limits of temperature which vegetables are capable of bearing, without destruction of their vitality, have not been determined with precision; it is, however, known, that, on the one hand, certain seeds may be boiled without being killed, and that, on the other, they are capable of bearing many degrees of freezing without suffering. In like manner, some plants are found to endure the most intense cold known upon the globe, while others sustain, occasionally, a temperature as high as 140°, as was observed by Dr. Coulter on the banks of the Rio Colorado.* The number of plants, however, capable of sustaining such extremes of temperature is small, and the greater part of the species known to us are proved to exist within the limits of 32° and 90°. What amount of temperature a given species will prefer, under different circumstances, seems reducible to no general rule, but has to be determined experimentally in each case, or is judged of by the known climate of which a plant may be a native. It is probable that every species has a constitution better suited to some particular amount of temperature than to any other, although it can bear a greater or less degree without sustaining injury.

Although many plants will live in a temperature much below

* The temperature borne by Oscillatorias in thermal springs is much higher than this; but no such power is possessed by *cultivable plants*.

that of freezing, yet no plant is able to grow unless the temperature is above 32°, for physical reasons that require no explanation. When temperature rises, the air contained in the minute cells of plants expands, the fluids become thinner, the excitability of the tissue is aroused, and, at the same time, insensible perspiration is commenced, the effect of which is to augment the absorbing powers of the roots, and thus to set the machinery of vegetation in action. The degree of temperature required to produce this effect is extremely variable in different species of even the same climate, and is, of course, much more variable between plants of different climates. For example, the common weeds called Chickweed, Groundsell, and Poa annua, evidently grow readily at a temperature very near that of 32°; while the nettles, mallows, and other weeds around them, remain torpid. In like manner, while our native trees are suited to bear the low temperature of an English summer, and, in most cases, suffer if they are removed into a country much warmer, such plants as the Mango, the Coffee, &c., inhabitants of tropical countries, soon perish, even in our warmest weather, if exposed to the open air.

When, in the case of a given plant, the temperature is permanently maintained at a much higher degree than the species requires, it is over-excited. If the atmosphere is preserved in a proportional state of humidity, the tissue grows faster than the vital forces of the plant are capable of solidifying it, its excitability is gradually expended, the whole of its organization becomes enfeebled, the vital functions are deranged, and a state of general debility is brought on.

According to Mr. Knight, the effect of an excessively high temperature is to cause, in unisexual plants, the production of male flowers only, while a very low temperature produces the contrary result. A Water Melon plant was grown in a house, the heat of which was sometimes raised to 110° during the middle of warm and bright days, and which generally varied, in such days, from 90° to 105°, declining during the evening to about 80°, and to 70° in the night; the air was kept damp by copious sprinkling with water, of nearly the temperature of the external air, and little ventilation was allowed. The plant, under these circumstances, grew with great health and luxuriance, and afforded a most abundant blossom; but all its flowers were male.

"This result," he says, "did not, in any degree, surprise me; for I had many years previously succeeded, by long-continued very low temperature, in making Cucumber plants produce female flowers only; and I entertain but little doubt that the same fruit-stalks might be made, in this and the preceding species, to support either male or female flowers in obedience to external causes." (*Hort. Trans.* vol. iii. p. 460.) It would seem that among Cucurbits, the power to form pollen in the nascent floral leaves is increased by heat; and that being so, to raise the temperature unduly, will have the effect of forming male flowers instead of females; on the contrary, cold seems to interfere with the formation of pollen, and in that case a low temperature must produce females in preference to males. In what precise way a high temperature acts upon the Cucumber, we cannot judge of. We see the effects, but we cannot perceive the immediate operation of the cause. It is, however, notorious, as has already been shown (Chapter VI.), that there is something at work in nature which does influence the fashioning of leaves into stamens or carpels; and there is reason to believe that the former are often the result of increased vigour. Thus, in the Hemp plant, the males may be known from the females by their larger size, and greater strength; and Fir-trees will bear cones in the feebleness of youth, but not their clusters of stamens, till the tree is in the prime of its age. And it may very well be, that in the case of the Cucumber, the application of unwonted heat may have, and probably does have, the effect of so increasing the vital force, as to throw into the nascent leaves of the flower-buds that quality which results in the development within their cells of the highly organized material called pollen.

One of our German translators says that in a moist atmosphere, and low temperature, Pelargoniums will form little or no pollen, while, under opposite circumstances, even mules produce pollen enough to become fertile.

Plants, forced in such an improperly high temperature, are soft and watery, with thin leaves, long joints, slender stems, and with no disposition to produce flowers. A slight lowering of temperature affects them more than a much greater lowering would have done under other circumstances; and a permanent abstraction of light readily destroys them. Their inability to decompose carbonic acid, and to assimilate their food in proportion to their rate of growth, prevents their becoming so green as is natural to them, and gives them a pallid hue; and, if it is their nature to form other colouring matter, that also is greatly diminished. But, if, with a preternatural elevation of

temperature, there is a proportionate abstraction of moisture, the loss of fluid, by perspiration and evaporation, goes on faster than the roots can make it good, or the tissue transmit it; old leaves "burn" and dry up; and young leaves perish as fast as they are formed.

Such being the result of preternaturally high temperature in dryness and in moisture, it is easy to conceive that, although such extremes cannot but be prejudicial, yet that they may be approached for particular purposes with advantage. A high temperature, and dryness, will be favourable to the formation of secretions of whatever kind, while a high temperature, with moisture, will lead to the production of leaves and branches only.

According to Humboldt, this happens to the Wheat grown about Xalapa in Mexico, which will not mount into ear, but produces an abundance of grass, on which account it is cultivated as a fodder plant.

An unnaturally low temperature is productive of evils of another kind. A certain amount of heat is necessary to each particular species, to enable it to grow at all: the immediate effect of heat being to rouse the vital forces, and to bring them into action. If the amount of heat to which a plant is exposed be sufficient to effect this purpose, the functions of the plant are natural and healthy; the consequences of exceeding it have been explained, those of diminishing it are not less disadvantageous. If the temperature to which a growing plant is exposed is not lowered so much as to destroy it, but just reduced to that point within which it will continue to live, the plant is brought, by the absence of a sufficient exciting cause, into a state not unlike that already described as resulting from over-excitement. It absorbs food from the earth and air, but it cannot assimilate it; its tissue grows, but is not solidified by the incorporation of assimilated matter; aqueous particles accumulate in the interior, a general yellowness ensues, partly from the want of a sufficient power of decomposing carbonic acid, and partly from inability to decompose the water collected in the interior. The consequence is a want of the means of forming the usual secretions; flavour, sweetness, nutritive

matter, are each diminished; and the power of flowering and fruiting is lost. If the unhealthiness of the plant is not so great as to prevent the production of flowers, still they may not expand, as often happens to double roses in cold summers in England; or, if the flowers do unfold, the fertilising power of the pollen is impaired or destroyed, and no production of seed takes place.

That the absence of healthy colour is sometimes owing to low temperature is certain. But the cause of the formation of different colours in different plants is too obscure a subject to suit the purpose of this work. It is, however, as well to observe that the effect of decomposing carbonic acid and exhaling oxygen is the production of a green colour, the intensity of which is, in general, in proportion to the decomposing cause, that is to say, to light: but that, if from any circumstances water is not given off, but is retained in the system and allowed to accumulate, the green colour is altered and changes to yellow; as if the vegetable blue, which must exist in combination with yellow in order to form green, were discharged. Such, indeed, is Macquart's explanation of the phenomenon; and it appears most conformable to theory and fact. It may be regarded as incontestable, that among the most efficient means of securing intense colours is free exposure to air as well as light. Experience tells us that, all other circumstances being equal, flowers, fruit, or leaves produced without artificial covering and at a moderate temperature, are much deeper in colour than those which are developed under glass, in highly heated buildings, where fresh air has little access.

Should the temperature be so much lowered as to result in freezing, a destruction of some plants and injury to others takes place, owing to physical causes quite different from those whose operation has been explained in the last paragraph. In what degree frost acts upon the vegetable fabric depends upon the specific nature of a plant, the least frost destroying some species, while others, under equal circumstances, endure any known amount of natural cold.

The manner in which COLD acts upon plants is one of the problems which have never yet been solved, and probably never will be. We see

its effects, but all attempts at investigating their causes have proved eminently unsuccessful. That a low temperature, or frost, acts differently upon different plants very nearly allied to each other is notorious; and this even where they are mere varieties of each other. The China Rose, for instance, resists any amount of English cold; the variety called the Tea-scented perishes, or suffers severely, in every ordinary winter. The gay-flowered Senecios of the Canaries, known in gardens under the name of Cinerarias, shrink from the mere approach of frost, and perish upon its first arrival; yet the Ragworts, and Mugworts, and Groundsels, all equally Senecios, can bear a Russian winter. In like manner Oaks, Chesnuts, Conifers, exhibit similar differences in their power of resisting frost.

It has been suggested that the fluids contained in different species of plants may themselves act differently in the presence of cold; just as oil of turpentine requires a temperature of 14° to freeze, while oil of Bergamot freezes at 23°, and Olive oil at 36°. But although this may be true to a limited extent, yet it by no means explains the phenomenon in question. The plant *x*, for instance, perishes from frost, while another, identical with it in nature, lives with impunity within two yards of it, both having been exposed to the same temperature. In this case the fluids of the two will be chemically the same, and yet the results are opposite. Again, the Long-leaved Pine (P. longifolia) is quite tender, while the Gerard Pine, exceedingly like it, is hardy; in this case there is no ground for supposing that the fluids contained in these species are different. In fact, except that all plants suffer from cold in proportion to the quantity of water they contain, we have no kind of evidence to show that the quality of their fluids has any material influence upon their power of resisting cold; for it is by no means true, as some too hastily assert, that resinous trees, like Conifers, are rendered hardy by the resin they contain; the Norfolk Island Pine and the Malay Dammar are tender, although both resinous and coniferous.

In this, as in so many other horticultural questions, the difficulty of the subject vanishes when we desist from a vain search after undiscoverables. It is by attempting to explain every phenomenon of life by the known laws of chemistry, electricity, and similar agencies, that we plunge into a labyrinth of perplexity—

> "And find no end, in wandering mazes lost."

But the moment we admit the presence everywhere among all plants of a *vital principle*, and thus recognise a direct analogy between plants and animals, the principle of life in the two kingdoms being identical, but differently manifested, then we tread on the firm ground consolidated by the march of ages, and find in the experience of animal

physiology the elucidation of what is obscure in that of vegetables. It is true that we then abandon the pursuit of first causes, and confess the vanity of that curiosity which nothing can satisfy; but we exchange rationalism for materialism, and we learn how to apply experience to daily uses.

It is an axiom in animal physiology, that "the general effect of cold on living bodies is a diminution of vital activity, which terminates, if the cold be intense, and its application continued, in death." (Pereira.) Hence it is to be inferred, that all living things whatsoever must finally perish beneath the influence of cold, provided it is severe enough, and prolonged enough. But living things have each their separate constitutional vitality, the power of which in resisting cold differs between species and species, or variety and variety, and even between individual and individual. It is a peculiarity derived from the great source of all things; a reality; inexplicable but indisputable; like light, and heat, and electricity. We see it manifested among plants between the yellow and the spider Ophrys, and the Tea Rose and the China Rose; as among animals between the ass and the zebra, the Negro and the Esquimaux, the terrier and the Italian greyhound. The moment we admit this principle, the mode of dealing with cold in gardens becomes analogous to that which experience tells us is effectual in the animal world. When a man is frozen, if he is suddenly thawed, he dies, or his limbs drop off; and so of frozen plants; nothing brings them such certain death as a sudden elevation of temperature. When the French retreated from Moscow, frozen noses and limbs were common, but immediate rubbing them *with snow* removed the tendency to congelation, and hence it became a practice for the unhappy men to look narrowly after each other's noses; for each could see his neighbour's although he could neither feel nor see his own. As long ago as the days of HIPPOCRATES it was known that a man who had had his feet frozen, lost them if plunged into warm water. It is exactly the same among plants; it is certain that a frozen plant, though tender, will not perish if it is gradually thawed, by being watered plentifully with cold water. Thus early Peas, Kidney Beans, and the like, are often saved by merely giving them a good watering the first thing in the morning before the sun is on them. It is asserted, and we doubt not with perfect truth, that wall trees, whose blossoms have been frozen, have had their crop saved by copiously syringing before sunrise. In all these cases it is, however, indispensable that the artificial thawing be practised before the solar rays can fall upon the object frozen; the sudden elevation of temperature, necessarily produced by morning sunbeams, renders all after-applications useless. And hence it is that the need of artificial thawing is altogether removed by planting tender things at the back of north or west walls, or behind screens. In such situations, sudden changes of temperature will not occur; but the

natural thawing must of necessity be very gradual. In the summer of 1849, an evergreen New Holland Beech, well known to be tender, was planted experimentally on the north of a ruined wall. In the succeeding winter it was remarked that the upper part of it was not screened from the sun; but about three-fourths of it next the ground was perfectly screened. On the approach of spring it was found that the part exposed to the sun was killed to the level of the wall; while the parts below the level were unchanged even in colour. When we add this to the cases of Fuchsias, Camellias, Tree Pæonies, &c., now becoming so generally well known, it seems impossible to doubt that, the vitality of plants and animals being the same, the same methods of treatment which are known to be requisite in the one case are equally effectual in the other.

The congelation of the aqueous particles contained in plants is in itself sufficient to cause such a derangement of function as may end in death, and other supposed causes may be left out of consideration. It will thus follow that, omitting differences arising out of the peculiar nature of different species, plants will suffer from frost in proportion to the abundance and fluidity of their secretions; those whose tissue is driest, and whose secretions are most dense, being the most capable of resisting frost. Hence young shoots are destroyed by a degree of cold which does not affect old shoots of the same species; and hence, also, the diminished capability of "unripe" shoots, or of plants growing in wet situations, or of trees when they first begin to vegetate, of enduring extreme cold.*

The effect of cold is, as has been seen, to diminish excita-

* M. De Candolle gives the following as the laws of temperature with respect to its influence upon vegetation :—

1. All other things being equal, the power of each plant, and of each part of a plant, to resist extremes of temperature, is in the inverse ratio of the quantity of water they contain.

2. The power of plants to resist extremes of temperature is directly in proportion to the viscidity of their fluids.

3. The power of plants to resist cold is in the inverse ratio of the rapidity with which their fluids circulate.

4. The liability to freeze, of the fluids contained in plants, is greater in proportion to the size of the cells.

5. The power of plants to resist extremes of temperature is in a direct proportion to the quantity of confined air which the structure of their organs gives them the means of retaining in the more delicate parts.

6. The power of plants to resist extremes of temperature is in direct proportion to the capability which the roots possess of absorbing sap less exposed to the external influence of the atmosphere and the sun.

bility; of heat, to stimulate it; but, if the latter stimulus were constantly equal, it may be conceived that the excitability would soon become impaired or expended. Nature has, however, provided against this result, not only by the fluctuations of temperature that occur at different periods of the day, but more particularly by the periodical fall of temperature at night and its rise during the day; an arrangement intimately connected with all the vital actions of vegetation. In the day, when light is strongest, and its evaporating and decomposing powers most energetic, temperature rises and stimulates the vitality of plants, so as to meet the demand thus made upon them; then, as light diminishes, and with it the necessity for excessive stimulus, temperature falls, and reaches its minimum at night, the time when there is the least demand upon the vital forces of vegetation; so that plants, like animals, have their diurnal seasons of action and repose. During the day, the system of a plant is exhausted of fluid by the aqueous exhalations that take place under the influence of sun-light; at night, when little or no perspiration occurs, the waste of the day is made good by the attraction of the roots, and by morning the system is again filled with liquid matter, ready to meet the demand to be made upon it on the ensuing day. No plants will remain in a healthy state unless these conditions be observed.* It is however to be remembered, that the amount of rest, or, in other words, the amount of difference between day and night, varies greatly in different countries, owing to circumstances imperfectly explained, but especially to radiation at night. Thus, at midsummer, the range of temperature is nearly 23° near London; in Australia, according to Sir Thomas Mitchell, 55° (see *Journ. of Hort. Soc.*, III. 283); but at Madras not more than 11°. Such peculiarities point to the different treatment demanded by Australian plants and by those from the peninsula of India.

From very careful comparison of the hourly temperature observed at Madras, from 1841 to 1845, Mr. Robert Thompson has calculated the following table, which exhibits the average *lowest* temperature at

* The incessant vegetation of arctic countries during their summer is an exception to this rule; but not such as to affect the general truth of the foregoing propositions.

night, the average *highest* temperature in the day, and the average *range* of daily temperature, in each month, at MADRAS, lat. 13° 4′:—

MONTHS.	Average lowest temperature.	Average highest temperature.	Average daily range of temperature.
January	72·7	81·1	8·4
February	72·6	83·6	11·0
March	76·9	87·6	10·7
April	81·0	91·4	10·4
May	82·4	92·9	10·5
June	82·0	93·0	11·0
July	81·5	92·3	10·8
August	80·1	90·2	10·1
September	79·2	88·5	9·3
October	77·4	84·9	7·5
November	74·3	82·8	8·5
December	73·0	80·6	7·6
Year	77·76	87·40	9·65

He also finds that the average *lowest* temperature at night, the average *highest* temperature in the day, and the average *range* of daily temperature, in each month, at CHISWICK, near London, from 1826 to 1853, are as follows:—

MONTHS.	Average lowest temperature.	Average highest temperature.	Average daily range of temperature.
January	30·78	42·59	11·81
February	32·42	45·83	13·40
March	33·72	50·74	17·01
April	36·89	57·42	20·53
May	42·90	64·79	21·89
June	49·16	71·86	22·70
July	51·98	74·36	22·38
August	51·01	73·04	22·03
September	46·64	67·33	20·69
October	41·36	58·76	17·40
November	36·22	49·93	13·71
December	33·95	45·33	11·37
Year	40·59	58·50	17·91

"From the preceding tables it will be seen, that the average daily range is nearly one-half less in a tropical climate than it is in the neighbourhood of London, and that it does not exceed 11°, the average being a little more than 9½°; whilst in the higher latitude it is nearly 18°."

The alternation of seasons seems to be intended to produce the like effects in a more extended manner, so that the summer season may be regarded as one long day, and the winter as a night of similar duration. The long days, bright light, and elevated temperature of summer, push the powers of vegetation to their limits; towards the end of the season excitability becomes impaired, all the vessels and perishable parts are worn out, leaves choke up, and can neither breathe nor digest, and the system of a plant, by the incessant exhalation of aqueous matter, becomes dried up, as it were, and exhausted. At that time temperature keeps falling, and light diminishing, till at last, upon the arrival of winter, neither the one nor the other is sufficient to excite the vital actions, and a plant sinks into comparative repose. At this time, however, its vital actions are not arrested; if they were, it would be dead or absolutely torpid: they are only diminished in intensity. The roots continue to absorb from the soil food, which is slowly impelled into the system, whence it finds no exit: it therefore gradually accumulates, and in the course of time refills all those parts which the previous summer's expenditure had emptied. In the meanwhile the excitability of the plant is recovered by rest, and may be even conceived to accumulate with the food that the absorbent system of the roots is storing up. At length, when the temperature of the season has reached the requisite amount, excitability is once more aroused, an abundance of liquid food is ready to maintain it, and growth recommences, rapidly or slowly in proportion to the amount of excitement, to the length of previous repose, and to the quantity of food which had been accumulated. In hot climates, where winter is unknown, the requisite periodicity of stimulus and rest is provided for by what are called the dry and the rainy seasons, the former being equivalent to the winter, the latter to the summer, of northern latitudes.

Table I.

MONTHLY MEAN TEMPERATURE OF THE EARTH AT 1 FOOT AND AT 2 FEET DEEP; AND THE MEAN MAXIMUM, MEAN MINIMUM, AND MEAN TEMPERATURE OF THE ATMOSPHERE FOR 10 YEARS, 1844—1853, INCLUSIVE.

FROM OBSERVATIONS MADE AT CHISWICK.

Years.	January.					February.					March.					April.				
	Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.		
	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.
1844	40·38	42·51	45·84	31·74	38·79	37·75	39·70	44·44	28·55	36·49	41·55	42·14	51·06	33·87	42·46	50·56	49·83	66·60	35·53	51·06
1845	39·90	40·93	45·90	31·61	38·75	35·64	37·57	41·43	24·71	33·07	37·79	38·37	45·51	31·48	38·50	45·71	45·40	60·20	36·63	48·42
1846	42·47	43·35	49·38	37·38	43·38	43·23	44·07	51·07	35·57	43·32	44·47	45·55	53·80	33·06	43·43	47·73	47·81	57·10	37·66	47·38
1847	37·17	38·66	39·35	29·14	34·24	37·60	39·03	42·17	27·43	34·80	40·22	41·03	50·77	29·45	40·11	44·70	45·05	55·03	33·53	44·28
1848	39·92	40·13	39·12	28·32	33·72	41·54	41·95	49·58	36·35	42·96	43·00	43·72	51·13	33·74	42·43	48·05	48·30	58·26	36·45	47·35
1849	40·50	42·11	45·35	33·77	39·56	43·50	43·03	49·50	33·21	41·35	42·79	43·70	50·09	33·03	41·56	44·45	45·31	54·26	33·83	44·04
1850	36·32	37·70	38·58	27·64	33·11	42·00	42·40	50·21	35·39	42·60	41·06	42·33	48·74	26·68	37·71	47·51	47·10	58·60	38·23	48·41
1851	41·74	42·92	47·09	33·06	40·07	39·73	40·98	47·46	29·03	38·44	41·48	41·95	49·93	33·51	41·72	46·18	46·28	55·20	33·93	44·56
1852	40·06	39·77	48·00	31·32	39·66	40·10	39·73	47·20	30·24	38·72	39·13	38·89	50·61	28·61	39·62	44·51	43·56	57·63	32·00	44·81
1853	42·29	42·16	47·35	34·35	40·85	36·32	36·73	38·32	26·75	32·53	38·14	38·11	47·32	27·51	37·41	45·30	43·90	55·36	35·53	45·44
—	40·07	41·02	44·59	31·83	38·21	39·74	40·51	46·13	30·72	38·42	40·96	41·57	49·89	31·09	40·49	46·47	46·25	57·82	35·33	46·57

Years.	May.					June.					July.					August.				
	Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.		
	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.
1844	54·77	54·34	65·42	42·68	54·05	61·36	59·38	76·60	49·30	62·95	63·61	62·48	76·42	52·19	64·30	60·12	60·58	71·68	47·71	59·69
1845	50.38	50·31	59·74	40·35	50·05	60·58	58·41	74·56	49·73	62·14	62·11	61·40	71·03	51·84	61·43	60·22	59·86	69·42	49·19	59·30
1846	55·38	54·55	68·29	44·03	56·16	64·73	63·10	81·13	51·80	66·46	64·40	63·84	77·61	54·29	65·95	64·74	64·53	74·29	54·03	64·16
1847	54·60	53·14	69·16	44·61	56·88	59·45	58·91	69·20	47·73	58·46	64·00	62·60	78·82	52·87	65·84	62·80	62·76	74·92	50·03	62·47
1848	56·40	55·38	75·25	41·00	58·12	60·15	59·98	69·80	49·36	59·58	62·22	62·12	73·93	50·25	62·09	60·77	61·03	69·32	48·16	58·74
1849	54·09	53·00	66·13	44·25	55·19	60·20	59·60	72·47	46·13	59·30	62·24	62·30	75·16	49·42	62·29	62·00	62·33	74·03	51·80	62·91
1850	51·22	50·86	61·97	40·32	51·14	59·98	58·58	73·43	45·10	59·26	61·87	61·12	72·67	51·16	61·91	61·53	61·45	71·51	47·26	59·38
1851	51·34	49·77	63·26	39·06	51·16	58·70	56·71	71·40	47·03	59·21	61·26	59·56	71·68	49·74	60·71	62·40	60·68	73·84	51·74	62·79
1852	51·42	49·30	61·61	41·29	51·45	56·71	54·13	67·23	48·80	58·01	65·48	62·79	81·16	54·06	67·61	62·32	60·56	75·32	52·03	63·67
1853	51·53	49·46	62·77	39·77	51·27	58·38	55·96	69·70	48·63	59·16	61·40	58·93	71·67	52·22	61·94	61·11	58·90	70·03	49·35	59·69
—	53·11	52·01	65·36	41·73	53·54	60·02	58·47	72·55	48·36	60·45	62·85	61·71	75·01	51·80	63·40	61·80	61·26	72·43	50·13	61·28

Years.	September.					October.					November.					December.				
	Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.			Earth.		Atmosphere.		
	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.	1 Foot.	2 Feet.	Max.	Min.	Mean.
1844	59·16	59·76	70·50	47·33	58·91	51·44	53·31	60·09	40·26	50·17	46·45	45·85	50·53	36·63	43·58	36·95	39·79	37·64	28·90	33·27
1845	56·31	57·45	64·57	40·63	52·60	51·12	52·45	60·03	39·90	49·96	46·20	47·73	52·80	35·73	44·26	41·48	43·47	48·32	32·67	40·50
1846	61·28	61·63	72·46	49·13	60·79	53·18	55·19	57·97	42·77	50·37	48·03	49·61	50·60	38·60	44·60	38·21	41·06	37·84	24·67	31·25
1847	55·88	57·02	64·80	42·00	53·40	52·77	53·74	60·58	43·67	52·12	47·96	49·71	52·33	36·90	44·61	44·14	45·67	47·00	35·19	41·09
1848	57·46	58·61	66·80	45·13	55·96	52·61	54·27	58·16	41·03	49·59	44·83	46·06	49·00	33·36	41·18	43·59	45·29	48·67	34·83	41·75
1849	59·16	59·76	67·56	47·96	57·76	52·34	53·70	58·32	40·84	49·58	46·96	49·05	50·33	33·60	41·99	41·32	43·01	43·42	30·93	37·17
1850	55·65	56·51	66·20	42·26	54·23	48·58	51·08	54·22	34·42	44·32	46·28	47·75	54·76	35·83	45·29	40·54	42·30	45·68	31·26	38·47
1851	56·55	55·70	66·80	43·50	55·15	52·65	52·00	59·00	43·51	51·25	41·18	41·96	43·96	27·76	35·86	41·26	41·06	44·67	33·09	38·88
1852	57·65	56·85	66·23	46·20	56·21	48·55	48·55	54·32	38·12	46·22	47·97	47·85	53·26	41·50	47·38	45·69	45·17	52·38	40·74	46·56
1853	56·36	55·61	67·00	45·90	56·45	52·00	53·62	58·77	41·22	49·99	44·28	47·30	48·13	32·16	40·15	38·19	41·56	39·03	25·96	32·50
—	57·54	57·89	67·29	45·00	56·14	51·52	52·79	58·14	40·57	49·35	46·01	47·28	50·57	35·20	42·89	41·13	42·88	44·46	31·82	38·14

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A very extensive and valuable series of temperatures, observed all over the world, has been compiled by Mr. Thompson, and published in the *Journal of the Horticultural Society*, Vol. IV., to which the reader is referred.

As plants have little power of generating heat, like animals, except in particular cases, and very locally,* they are principally dependent upon the media that surround them for the heat which they require. Considering the great importance of heat in their economy, it is, for the purposes of gardening, necessary to ascertain what proportion is usually borne to each other, in different countries, by the temperatures of the earth and atmosphere, the chief media by which plants can be affected. Upon the temperature of the atmosphere there are numerous observations in many countries; upon that of the earth much fewer. It has been considered that the temperature of springs affords sufficient evidence of the temperature of the earth; but, so far as vegetation is concerned, this evidence is unsatisfactory. Springs, deriving their origin from considerable depths, have a nearly uniform temperature all the year round: but the temperature of the earth's surface varies with the seasons; is extremely different in summer and winter; and is affected by the quality of the soil, in proportion as that is more or less absorbent and retentive of heat. What we want to know, as respects vegetation, is, not the mean temperature of the earth at some distance from its surface, but the temperature immediately below the surface; *i. e.* of that part of the soil which the roots of plants penetrate, and whence they derive their food. It is also requisite that this should be ascertained monthly, so as to furnish the means of comparing the terrestrial temperature with the periodical state of vegetation. Such being the case, the temperature indicated by springs will be too high in winter, and too low in summer, a most material error.

I am indebted to Mr. Robert Thompson for the following highly important tables indicating the ascertained temperature of the earth in various parts of the world.

* Allusion is here, of course, made to the extrication of heat during the periods of flowering and germination, phenomena which have no obvious connexion with cultivation.

II.—Mean Temperature of the Earth and of the Air at Chiswick, lat. 51° 29′; on the average of 10 years, 1844—1853.

Months.	Mean Temperature of the Earth. 1 foot.	2 feet.	Mean of 1 and 2 feet.	Mean Temp. of Air.	Difference. Earth warmer than air.	Earth colder than air.
January	40·07	41·02	40·54	38·21	2·33	
February	39·74	40·51	40·12	38·42	1·70	
March	40·96	41·57	41·26	40·49	0·77	
April	46·47	46·25	46·36	46·57		0·21
May	53·11	52·01	52·56	53·54		0·98
June	60·02	58·47	59·24	60·45		1·21
July	62·85	61·71	62·28	63·40		1·12
August	61·80	61·26	61·53	61·28	0·25	
September	57·54	57·89	57·71	56·14	1·57	
October	51·52	52·79	52·15	49·35	2·80	
November	46·01	47·28	46·64	42·89	3·75	
December	41·13	42·83	41·98	38·14	3·84	
	50·10	50·30	50·20	49·07	1·13	

From the above it appears that, in the first three months of the year, the thermometer at the depth of two feet indicates a somewhat higher temperature than that at one foot deep. The latter, from April till August, is higher than the one at two feet. But from September till the end of the year, or in fact till April, the ground at two feet deep is warmer than at one foot. Again, it will be seen that in April, May, June, and July, the earth at one and two feet deep is on the average nearly a degree colder than the air; but in all the other months it is warmer.

III.—Temperature of the Earth and of the Air at Upsal, lat. 59° 52′; on the average of 8 years, 1838—1845. (Calculated from data in a *Mémoire sur la Température de la Terre à Upsal, par A. J. Ångström.*)

Months.	Mean Temperature of the Earth.					Mean Temp. of the Air.	Difference. Mean of Earth at 2 ft. and 3 ft. 10¾ in.	
	2 ft. deep.	3 ft. 10¾ in. deep.	5 ft. 10 in. deep.	9 ft. 9 in. deep.	Mean of 2 ft., and 3 ft. 10¾ in.		Warmer than Air.	Colder than Air.
January	33·55	36·85	41·27	45·38	35·20	23·70	11·50	
February	31·43	35·25	37·57	43·36	33·34	19·96	13·37	
March	31·16	34·22	36·32	41·84	32·69	25·65	7·03	
April	34·87	34·85	37·90	40·66	34·86	37·17		2·31
May	46·44	43·44	39·86	41·15	44·94	49·07		4·13
June	56·49	50·38	48·53	44·47	53·43	57·61		4·18
July	60·12	55·10	51·27	48·90	57·61	60·64		3·03
August	60·96	57·79	53·78	52·36	59·37	60·52		1·14
September	56·11	54·91	53·59	54·22	55·31	52·06	3·44	
October	45·57	48·48	49·81	53·66	47·02	40·30	6·72	
November	38·54	42·63	47·18	51·21	40·59	31·49	9·09	
December	35·21	38·65	41·41	48·00	36·93	28·41	8·51	
	44·26	44·19	44·22	47·11	44·22	40·68	3·54	

Notwithstanding the intensity of the Scandinavian winters, it appears that the thermometer at two feet deep falls very little below freezing, although the mean temperature of the air is far below that experienced in this country in the most severe winters. The difference between the temperature of the earth at 2 feet and 3 feet 10¾ inches, on the average, and that of the air, is no less than 13·37° in the month of February. This great difference is doubtless owing to radiation of heat from the earth being prevented by a covering of snow. From April till August, the air, as at Chiswick, is warmer than the earth.

IV.—Temperature of the Earth and of the Air at Copenhagen, lat. 55° 41′; on the average of 8 years, 1842—1849. (*Transactions of the Royal Society of Denmark.*)

Name.	Mean temp. of the earth at 12 feet deep.	Mean temp. of air.	Difference. Earth warmer than air.	Difference. Earth colder than air.
January	36·62	31·99	4·63	
February.	34·34	29·60	4·74	
March.	35·25	33·60	1·65	
April	40·65	43·61		2·96
May	50·34	52·98		2·64
June	58·71	60·60		1·89
July	60·36	62·33		1·97
August	61·77	63·12		0·35
September	57·34	54·62	2·72	
October	50·45	48·02	2·33	
November	44·24	40·06	4·18	
December	39·79	34·95	4·74	
	47·50	46·39	1·11	

Earth warmer than the air in winter, early spring and autumn, but colder during the summer, are the results of observations made at Copenhagen by Mr. Weilbach. On the year, the average excess of the ground temperature above that of the air is almost the same as at Chiswick, the former being 1·11, the latter 1·13.

V.—Mean Temperature of the Earth and of the Air at Dodabetta, Nilgherry Hills, lat. 11° 23′; elevation 8640 feet above the level of the sea. (*Met. Obs., by T. G. Taylor, Esq.*)

	Temperature of the Earth, at 1 foot deep.			Temperature of the Air.			Difference.	
Months.	Max.	Min.	Mean.	Max.	Min.	Mean.	Earth warmer than Air.	Earth colder than Air.
January .	62·00	54·00	58·00	58·60	44·40	51·50	6·50	
February.	57·70	54·00	55·85	56·70	45·90	51·30	4·55	
March. .	63·40	58·30	60·85	61·70	47·10	54·40	6·45	
April . .	62·40	58·60	60·50	61·30	51·20	56·25	4·25	
May . .	63·60	59·60	61·60	62·40	49·90	56·15	5·45	
June . .	56·80	54·70	55·75	54·90	46·10	50·50	5·25	
July . .	56·30	53·30	54·80	54·40	47·90	51·15	3·65	
August .	57·80	53·80	55·80	55·10	46·80	50·95	4·85	
September	54·40	53·70	54·05	54·90	47·40	51·15	2·90	
October .	58·40	54·40	56·40	55·60	48·10	51·85	4·55	
November	59·30	53·80	56·55	55·60	47·20	51·40	5·10	
December	55·70	51·00	53·35	54·00	45·10	49·55	3·80	
	58·98	54·93	56·95	57·10	47·26	52·18	4·77	0·0

At this latitude and elevation, the average temperature of the earth at one foot deep is higher throughout the year than that of the air: the average difference being 4·77. The greatest difference occurs in January and March, and the least in September.

VI.—Temperature of the Earth and of the Air at Dorjiling, lat. 27° 3′; elevation 7430 feet above the level of the sea. (From data in *Hooker's Himalayan Journal.*)

Months.	Mean temp. of the earth at 2¼ ft. to 3 ft. deep.	Mean temp. of air.	Difference.	
			Earth warmer than air.	Earth colder than air.
January	46·0	40·0	6·0	
February.	48·0	42·1	5·9	
March	50·0	50·7		0·7
April	58·0	55·9	2·1	
May	61·0	57·6	3·4	
June	62·0	61·2	0·8	
July	62·2	61·4	0·8	
August	62·0	61·7	0·3	
September	61·0	59·9	1·1	
October	60·0	58·0	2·0	
November	55·0	50·0	5·0	
December	49·0	43·0	6·0	
	56·2	53·5	2·7	

Here, as in the Nilgherry Hills, the temperature of the earth is in every month above that of the atmosphere, excepting in March. The descrepancy, as in lower situations and higher latitudes, is in favour of the earth being on the average warmer than the air, but more especially so in winter. They nearly coincide in March and August.

VII.—Temperature of the Earth and of the Air in the Plains of Bengal.

At Dacca, lat. 23° 50′, and 72 feet above the level of the sea, Dr. Joseph Hooker found the temperature of the earth at the depth of two feet seven inches was 84°, in the end of May; and the mean temperature of the air ranged at the same time from 75·3 to 95·5; its mean therefore nearly corresponded with that of the earth. At ten stations in these plains, varying from 72 to 131 feet above the level of the sea, the mean of the indications of the ground thermometer during May was 85·53; the approximate mean temperature of the air was 82·30; the difference therefore was only 3·23.

VIII.—TEMPERATURE OF THE EARTH AND AIR, AS OBSERVED BY CAPTAIN NEWBOLD AT BELLARY, ON THE CENTRE OF THE TABLE-LAND OF PENINSULAR INDIA, LAT. 15° 5′ N.; ELEVATION 1600 FEET ABOVE THE LEVEL OF THE SEA. In the hot month of May, sky unclouded; soil reddish and light in texture, completely sheltered by a thatched roof; depth of thermometer for temperature of the earth one foot.

	Sunrise.		Two P.M.	
	Earth.	Air in Shade.	Earth.	Air in Shade.
First Day	86·5	81·0	91·3	96·5
Second Day.	85·0	78·0	89·0	92·0
Third Day	85·5	78·5	90·0	95·0
Fourth Day.	87·0	75·0	89·0	92·0
	86·0	78·1	89·8	93·9

Mean temperature of the earth one foot deep at sunrise and 2 p.m. . . . . 87·9
Mean temperature of the air at sunrise and 2 p.m. . . . . 86·0

Difference 1·9

From the above it appears that the earth was nearly four degrees warmer at 2 p.m. than at sunrise; and that on the average it was nearly two degrees warmer than the air.

IX.—VARIATIONS OF TEMPERATURE IN NEW HOLLAND, ACCORDING TO SIR THOMAS MITCHELL'S OBSERVATIONS.

a. *Noonday Temperatures.*

Lat.	Months.	Averages.	Max.	Min.
29° s.	Nov. Dec.	of 3 observations 102°	103°	62°
32° s.	Jan. Feb.	,, 18 ,, 97½	115	73
31° s.	Feb. March	,, 17 ,, 90	110	80
30° s.	March	,, 20 ,, 95	105	84

b. *Night Temperatures.*

			Occasional Temperature at Sunrise.		
Nov. Dec.,	averaging at noon	102°	62°	58°	61°
Jan. Feb.,	,, ,,	97½°	61	59	47
Feb. March,	,, ,,	90	61	54	48
March,	,, ,,	95	68	55	47

(See *Journal of Horticultural Society*, III. 297.)

X.—Mean Temperature of the Earth and of the Air at Trevandrum, in India, lat. 8° 30′, N.; elevation 200 feet above the level of the sea. As observed by John Caldecott, Esq., Astronomer to the Rajah of Travancore, during the years 1843, 1844, 1845.

Months.	Mean Temperature of the Earth. 12 feet.	6 feet.	3 feet.	Mean Temp. of the Air.	Difference. Earth at 3 feet. Earth warmer than air.	Earth colder than air.
January . .	85·528	85·618	84·954	78·930	6·024	
February .	85·784	86·625	86·838	80·386	6·452	
March . .	86·373	88·110	88·789	82·730	6·059	
April . . .	86·916	88·527	89·614	83·370	6·244	
May . . .	. . . .	88·224	88·413	81·603	6·810	
June . . .	86·878	86·883	85·012	79·023	5·989	
July . . .	86·537	85·114	83·250	78·450	4·800	
August . .	85·894	84·736	83·566	78·990	4·576	
September .	85·633	85·133	84·575	79·973	4·602	
October . .	85·680	85·632	84·722	79·076	5·646	
November .	85·651	85·271	84·622	79·750	4·872	
December .	85·607	85·303	84·228	78·030	6·198	
	86·043	86·264	85·715	80·025	5·690	000

Here, as at Dodabetta, the mean temperature of the earth averages higher than that of the air in every month throughout the year, the excess on the whole being upwards of 5½ degrees. At Trevandrum, it appears that the highest mean temperature of the earth at three feet deep occurs in April, and is nearly 90° ; the lowest occurs in July, when it is a little above 83°. Its mean range is between 6 and 7 degrees. The mean temperature of the air is highest in April, 83·37°, and lowest in December, 78° ; so that the difference between the hottest and coldest months is only 5 or 6 degrees.

The preceding tables exhibit the relative temperature of the earth and air at a number of places very differently situated both as regards latitude and elevation ; from Upsal in lat. 59° 52′, to Trevandrum in lat. 8° 30′ ; and from Chiswick, Copenhagen, and the Plains of Bengal, all near the level of the sea, to Dodabetta and Dorjiling, respectively 8640 and 7430 feet above that level. The general results deduced from these tables are as follows :—

First.—That in all cases the mean temperature of the earth exceeds that of the air, on the average of the whole year.

Second.—That in some localities the monthly mean temperature of the earth is in every month, more or less, higher than that of the air.

Third.—That in other localities the mean temperature of the air exceeds that of the earth in the summer months only, or from April till July or August; but from September till March, the earth is warmer than the air.

The excess of mean temperature of the earth above that of the air, on the average of observations taken at different places, is as follows:—

Chiswick	1·13
Upsal	3·54
Copenhagen	1·11
Dodabetta	4·77
Dorjiling	2·70
Plains of Bengal	3·23
Bellary	1·90
Trevandrum	5·69
Average	3·01

From this it will be seen that at these places the average difference between the temperature of the earth and the air is least at Copenhagen, and greatest at Trevandrum. But it must not be thence inferred that the difference is uniformly greater within the tropics than in high latitudes, for we have, on the other hand, a greater difference at Upsal, than at Bellary on the centre of the table-land of India.

There appears to be no series of direct observations upon the superficial temperature of the earth, at the different periods of vegetation, in other countries; but some statements are to be found, here and there, concerning the temperature occasionally observed, from which it is to be inferred that the earth is heated, at least for short periods of time, very much above the atmosphere, and it is probable that this excessive elevation of temperature is necessary to the healthy condition of many plants. From some interesting observations communicated to me by Sir John Herschel, it appears that the temperature of the earth at the Cape of Good Hope is often excessive. On the fifth of December, 1837, between one and two o'clock in the day, he observed the heat under the soil of his bulb garden, to be 159°; at three p.m. it was 150°, and even in shaded places 119°: the temperature of the air in the shade, in the same garden, at the same period, was 98° and 92°. At 5 p.m. the soil of the garden, having been long shaded, was found to have, at four inches in

depth, a temperature of 102°. "On the third of December, a thermometer buried a quarter of an inch deep, in contact with a seedling fir of the year's planting, quite healthy, and having its seed-leaves marked as follows:—at $11^h\ 25^m$ a.m. 148·2°, at $0^h\ 48^m$ p.m. 149·5°, at $1^h\ 34^m$ p.m. 149·8°, at $1^h\ 54^m$ p.m. 150·8°, and at $2^h\ 46^m$ p.m. 148°." Sir John Herschel observes that such observations "go to show that at the Cape of Good Hope, in the hot months, the roots of bulbous and other plants which do not seek their nourishment very deep, must frequently, and, indeed, habitually, attain temperatures which we can only imitate in our hothouses by actually suspending over the soil plates of red-hot iron. For it must be remarked, that heating the ground *from below* would not distribute the temperature in the same way."

Memoranda concerning the temperature immediately below the surface of the earth, occasionally remarked in different countries:—

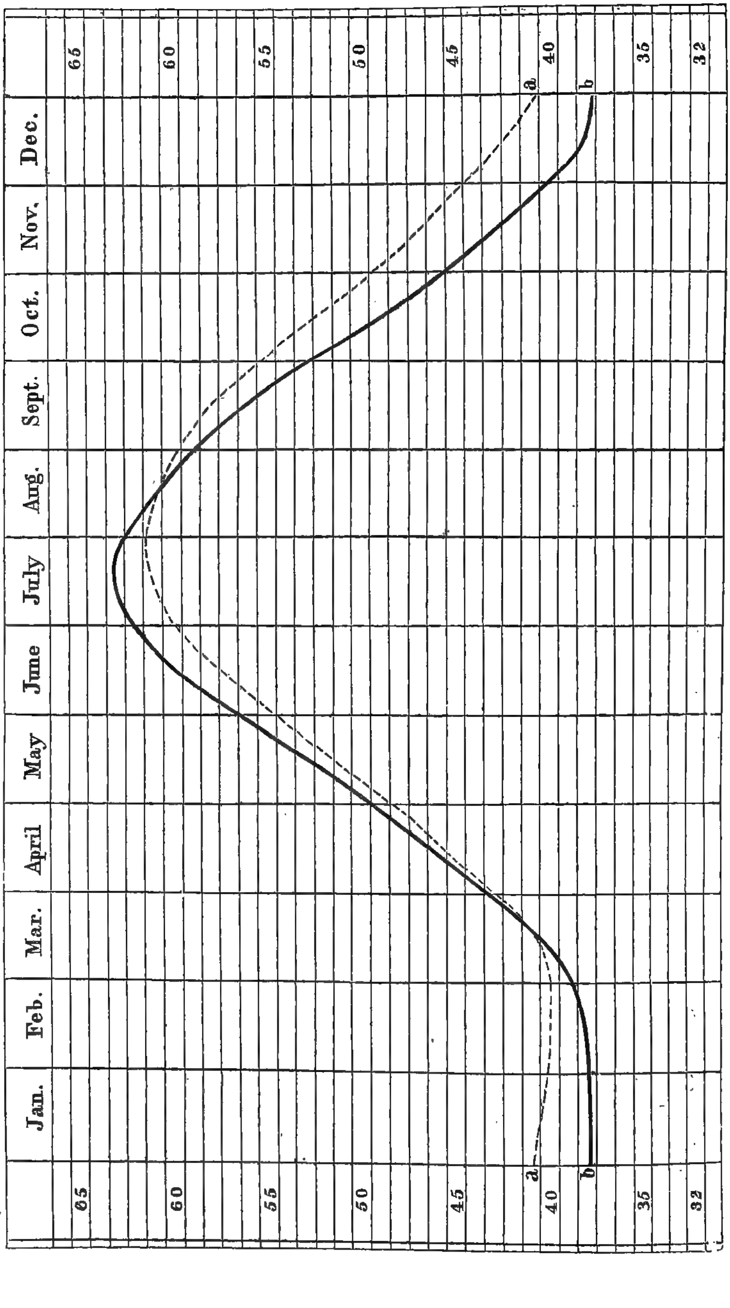
Egypt. . . .	133°—144°	According to Edwards and Colin.
Tropics . . .	Often 126°—134°	Humboldt, *Fragm. As.*
Oronoco . . .	Coarse white sand at 140°, the atmosphere being 84·5°	Humboldt.
France . . .	118°—122°; once 127°, the atmosphere being 91·5°	Arago, as quoted by Edwards and Colin.
Chile	113°—118° among dry grass	Boussingault.
New Grenada .	85° usual summer temp. one foot below surface .	Hay, in *Loudon's Gard. Mag.*, vi. 437.
Cape of Good Hope . . .	159° under the soil of a bulb garden	Herschel (*MSS.*).
Bermuda. . .	142° thermometer barely covered	Col. Emmet.
Lantao, China	Water of rice fields 113°; adjacent sandy soil much higher; for towards midday the black sides of the boat were 142·50°	Meyen.

These observations seem to confirm the late Mr. Harvey's suspicions, that the real force of the sun's rays in tropical countries is still far from being ascertained. When, therefore,

we are informed by travellers that the temperature in the sun, at Gondar, has been seen to be 113° (Bruce); at Benares 110°, 113°, 118° (Harvey); or at Sierra Leone, 138° (Winterbottom); it must be supposed that, in reality, the temperature would have been found much higher in those places had more efficient means of observation been employed. Mr. Foggo, indeed, succeeded, by means of a large thermometer, having the ball covered with black wool, and fully exposed to the direct rays of the sun, unsheltered from the wind, in obtaining, at Edinburgh, on the 29th of July, at $3^h\ 10^m$ p.m., an indication of 150°, and at 2^h p.m. of 140°, while another instrument, similarly prepared, and resting in contact with herbage, was found to indicate only 119° and 110°; so that, as Mr. Foggo remarks, a difference of 30° was produced in these cases solely from the manner in which the instruments were exposed. (*Edinburgh Philosophical Journal*, No. xxvii.)

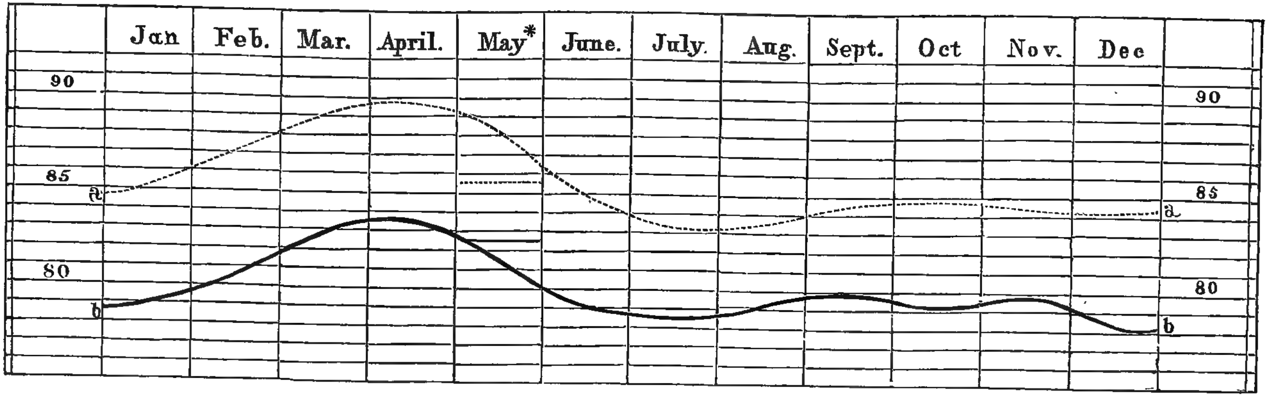
For horticultural purposes a far more extensive series of observations than we at present possess requires to be made at a great number of different places, with a view to determine the connexion between the temperature of the soil and the seasons of vegetation. In making these, the nature of the soil in which the thermometers are plunged should, among other circumstances, be very precisely described; for it is obvious that the result will be essentially affected by the peculiar conducting power of the earth. In the meanwhile the two following diagrams, and the observations which follow, for which we are indebted to Mr. Thompson, throw much light upon this obscure subject.

"It will be seen from the diagram of the mean monthly temperature of the earth and air at Chiswick, that the earth, at two feet deep, is warmer than the air by two or three degrees at the commencement of the year; but the lines representing the progress of the respective temperatures gradually approximate, the ground one falling and the air rising a little towards the end of February. In March, both take a decided start, and towards the end of that month the lines coincide, and then the air temperature is higher than that of the earth till August, when the contrary takes place. The mean temperature of the



TEMPERATURE OF THE EARTH AND OF THE AIR AT CHISWICK. *aa*, REPRESENTS THE TEMPERATURE OF THE EARTH AT TWO FEET DEEP; *bb*, THE MEAN TEMPERATURE OF THE AIR.

TEMPERATURE OF THE EARTH AND OF THE AIR AT TREVANDRUM. *aa*, REPRESENTS THE TEMPERATURE OF THE EARTH AT THREE FEET DEEP; *bb*, THE MEAN TEMPERATURE OF THE AIR.



* In this column, two horizontal lines will be observed: the dotted one represents the temperature of the earth, and the one below it the mean temperature of the air, at ten stations in the plains of Bengal, in the month of May. Their difference is little more than three degrees.

air begins to decline about the middle of July; that of the earth about the 1st of August; and as the latter does not rise so high nor so quickly with a generally ascending temperature, so it falls more slowly and not so low as the air when the general temperature is declining. The diagram for the temperatures at Trevandrum, exhibits two nearly parallel curved lines, the earth averaging a little more than five and a half degrees higher than the air. The greatest approximation is in August and September, as is generally the case at other places in the tropics, and likewise in colder latitudes; but in the latter there is a coincidence of the lines in March or April which is not followed at Trevandrum. On the contrary, the powerful sun-heat which there prevails in the months of February, March, and April, appears to heat the earth more than the air, till the setting in of the rainy season, in consequence of which the earth is lowered from its maximum, 89·61 in April, to its minimum 83·25 in July, or more than 6°; whilst the air is lowered, during the same period, scarcely 5°.

"From the foregoing facts and diagrams we can form a tolerably correct idea of the relation which the monthly mean temperature of the soil bears to the monthly mean temperature of the air throughout the year. The latter is known at a vast number of places; but that of the earth comparatively at very few. It may, however, be estimated with sufficient accuracy for all practical purposes connected with horticulture and agriculture. For example, we may take the tables and diagram for Chiswick as our guide, for all places having nearly the same monthly and annual temperature. Where the winters are colder, as at Copenhagen, we must add 2° or 3° more than for Chiswick to the temperature of the air in January, in order to obtain, approximately, the temperature of the soil for that month. In April, throughout the world, from lat. 60° to lat. 30°, the mean temperature of the earth and air may be considered to average alike, or to differ rarely more than 1°. From April to July, subtract about 2° from the monthly mean of the air for that of the earth. In August the temperatures again coincide. The earth, after this, maintains a higher temperature than the air throughout the remaining months; so that in

September, 1° to 2°; October, 2° to 3°; and in November and December, between 3° and 4° must be added to the mean temperature of the air, in these months respectively, in order to obtain the approximate mean temperature of the soil. This will apply to all places having a climate resembling that of Chiswick. But where the temperature of the air falls very low in the end of autumn, and beginning of winter, as at Upsal, where the mean of the air in October is 12° below that in September, 6 or 7° must be added to the mean of the air, for the mean temperature of the earth; and 8 or 9° in each of the two following months. On the contrary, where the winters are milder than at Chiswick, the difference between the earth and air temperatures will be somewhat less than that which appears in the table, and represented in the diagram for that place.

"Within and near the tropics the earth, it appears, is, on the average, always warmer than the air by several degrees. In some months, and at some places, both temperatures are nearly alike; and in other instances they differ as much as 6 or 7°, much depending on the fall of rain, and the nature of the soil. If we add 2° to the temperature of the air, in June, July, August, and September, and 4° in the other months, we shall approach the monthly mean temperature of the soil between 0° and 30° latitude, sufficiently near for all practical purposes; certainly much nearer than the temperature to which plants from that soil have been subjected by artificial treatment in this country."

It must, however, be understood that such calculations are necessarily uncertain, and can only be taken as rough approximations to truth, near enough for practical purposes, but nothing more. An infinite multitude of circumstances, reducible within no general rules, modify all such estimates.

As regards the Indian seasons, the greater part of the west and south coast of the peninsula is so damp that the growing and flowering season lasts all the year round. Even of Rice there are, according to Buchanan Hamilton, two crops in Malabar:—one sown in May, transplanted in June, and reaped in July; another sown in August, transplanted in September and October, and reaped in November. In Northern India the growing season for tropical crops—Rice, Millet, &c.—generally

K 2

speaking begins with the rains (May and June), and lasts all the rains; August and September are fruiting months, and these are followed by rest for such crops. Then, however, Oats, Barley, Tobacco, Wheat, Sesamum, Poppy, and all Pulses are put in to be reaped in spring. In Malabar on the average the seasons are the same, but the dry season is so damp that the most tropical crops can be raised all the year round.

Of course in the Southern Hemisphere the seasons are the reverse of those in the Northern, midwinter in Sydney corresponding with midsummer in Europe.

In the tropical parts of America, where Humboldt found the mean temperature of the coldest month not to be lower than 79·16° at Cumana, we shall be justified in concluding that the temperature of the earth's surface never falls permanently below that amount; and as the mean summer temperature of the place was found to be 82·04°, so it is probable that the earth will have something above that degree of warmth, on an average, in the summer.

For the warmest month, this great observer gives 84·38° as the mean, which corresponds remarkably with the temperature a foot below the surface in New Grenada, where, according to a correspondent of Mr. Hay, it is 85° during summer, "as a gentleman, a planter there, wrote home for his information." (See *Loudon's Gard. Mag.*, vi. 437.)

BOOK II.

OF THE PHYSIOLOGICAL PRINCIPLES UPON WHICH THE OPERATIONS OF HORTICULTURE ESSENTIALLY DEPEND.

All operations in horticulture depend for success upon a correct appreciation of the nature of the vital actions described in the last Book; for although there have been many good gardeners entirely unacquainted with the science of vegetable physiology, and although many points of practice have been arrived at altogether accidentally, yet it must be obvious that the power of regulating and modifying knowledge so obtained cannot possibly be possessed, unless the external influences by which plants are affected are clearly understood. Indeed, the enormous difference that exists between the skill of the present race of gardeners and their predecessors can only be ascribed to the general diffusion, that has taken place, of an acquaintance with some of the simpler facts in vegetable physiology.

In attempting to apply the explanations of science to the routine of horticultural practice, it appears desirable, in order to avoid frequent repetition, that mere details should be omitted, and that those general operations should alone be adverted to which, under many different modifications, and in various forms, constitute the foundation of every gardener's education.

CHAPTER I.

OF BOTTOM HEAT.

THIS term is, in common practice, made use of only in those cases where the temperature of the soil in which plants grow is artificially raised considerably above that which we are acquainted with in England; and there seems to be a general idea that such an artificial elevation of temperature is only necessary in a few special instances. It has, however, been shown (p. 125) that the mean temperature of that part of the soil in which plants grow is universally something higher than that of the air by which they are surrounded, and consequently it appears that nature, in all cases, employs some degree of bottom heat as a stimulus and protection to vegetation. At the same time, it must be admitted that, in some cases, the amount is extremely small; for Von Baer found Ranunculus nivalis and Oxyria reniformis flowering in Nova Zembla, where the soil was not warmed above 34½°; and, in Jakutzsk, Erdmann states that Summer Wheat, Rye, Cabbages, Turnips, Radishes, and Potatoes are cultivated, although the ground is not thawed above three feet in depth.

How the warmth of the soil may act as a protection to plants will be easily understood. A plant is penetrated in all directions by innumerable air passages and chambers, so that there is a free communication between its extremities however far they may be apart. It may therefore be conceived that if, as necessarily happens, the air inside the plant is in motion, the effect of warming the air in the roots will be to raise the internal temperature of the whole individual; and the same is true of its fluids. Now, when the temperature of the *soil* is raised to 150° at noonday by the force of the solar rays, it will retain a considerable part of that warmth during the night: but the temperature

of the *air* may fall to such a degree that the excitability of a plant would be too much and suddenly impaired, if it acquired the coldness of the medium surrounding it; this is prevented, we may suppose, by the warmth communicated to the general system, from the soil, through the roots; so that the lowering of the temperature of the air, by radiation during the night, is unable to affect plants injuriously, in consequence of the antagonist force exercised by the heated soil. It is not improbable that this fact may be hereafter applied in gardening to the acclimatising of half-hardy plants. Were an open border heated artificially in the winter, it is possible that plants might endure an amount of cold upon their stems and leaves, which in the absence of such heat would be fatal to them. An experiment upon this subject was tried some years ago, and although it was conducted so negligently and unskilfully, as not to justify any inference being drawn from it, yet the result, such as it was, was full of promise.

That elevating the temperature of moist soil produces an unusual degree of vigour in plants unaccustomed in nature to such an elevation is a fact which requires no proof; it is attested by the condition of vegetation round hot springs, and in places artificially heated by subterraneous fires; and this has probably been the cause of the employment of tan and hot-beds, by which means bottom heat has been generally obtained for rearing delicate species, and especially seeds. But if this stimulus acts in the first instance beneficially in all cases alike, it soon becomes a source of mischief in those species which are natives of climates where such terrestrial heat is unknown, the latter "drawing up," as the saying is, becoming weak and sickly, and speedily presenting a diseased appearance.

On the other hand, it is equally well known that, unless the temperature of the soil be raised permanently to at least 75°, the seeds of tropical trees will not germinate; or, if they do, they push forth feebly, and from the first present the sickly appearance of plants suffering from cold. Hence arises the impossibility of making the seeds of tropical plants germinate when sown in the open air in this country, where the mean temperature of the earth seldom rises to 65°, and that for only short periods of time. It is, therefore, obvious that all plants require some bottom heat; but the amount varies with their species, and the only means of determining what the amount should be

is afforded by the known degree of warmth of the climate of which a plant may be a native.

When plants are cultivated in glass houses, there is little difficulty in supplying them with the amount of bottom heat which they may require; but this can either not be effected at all, or only to a limited degree, by a selection of soils and situations, when plants are cultivated in the open air; and hence one of the many difficulties of acclimatising in a cold country the species of a warmer climate. It is true that plants will exist within wide limits of temperature, and, consequently, a few degrees of difference in the natural bottom heat to which they are exposed may not affect them so far as to destroy them; but it cannot be doubted that the conditions most favourable to their growth are those which embrace a temperature rather above than below that to which they are accustomed in their native haunts.

The Orange-tree is found in perfection where the temperature of the soil may be computed to rise to 80° or 85°, and never to fall below 58°, as in the Bermudas, Malta, and Canton. How injudicious, then, is our practice of exposing it during summer to the open air, in tubs, where the soil scarcely rises in temperature above 66°, and preserving it during winter in cold conservatories, the soil of which often sinks to 36°; under such circumstances the Orange exists indeed, but where are the perfume and juiciness of its fruit, and where the healthy vigour of its noble foliage? The Vine cannot be grown in the open air of this country to any useful purpose, except when trained to walls, in soils and situations unusually exposed to the beams of the sun; it is only then that it can obtain for its roots such a permanent warmth as 75° which it will have at Bordeaux, or 80° in Madeira.

It may hence be considered an axiom in horticulture, that *all plants* require the soil, as well as the atmosphere, in which they grow, to correspond in temperature with that of the countries of which they are natives. It has also been already shown, that the mean temperature of the soil should be above that of the atmosphere. How much above depends upon climate and season. The *mean* difference in favour of the

ground at Chiswick is only 1°13 as is shown at p. 125, while that of Trevandrum, an Indian station, is 5°69. But it must be remembered that, *disregarding means*, the monthly temperature exhibits very much greater differences. Thus at Chiswick the earth is nearly 4° warmer than the air in December, and that of Trevandrum is nearly 6½° warmer in the month of February: these differences are themselves insignificant when contrasted with what occurs at Upsal (p. 119), where the earth is warmer than the air by 13°37 in the month of February. It seems evident that in the examples of a high winter temperature of the earth in severe latitudes, we have an example of the protection thus afforded to the vitality of plants in the manner suggested in the preceding page.

There can be no sort of doubt, that the advantage derived from draining cold countries, is owing greatly, if not exclusively, to the augmented temperature which attends the removal of stagnant water from land. UNDERGROUND CLIMATE is not less important than that which is experienced above ground. It is only by perfect and skilful drainage that underground climate is improved. No other means of effecting it on a large scale are known; it is probable indeed that the superiority of common littery stable manure over artificial composts, as well as the increased efficacy of the latter when mixed with the former, is a mere exemplification of the advantageous effects of perfect drainage.

Some believe that the advantage of drainage consists in removing water. But water is not of itself an evil; on the contrary it is the food of plants, and its absence is attended with fatal results. It is the excess of water which injures plants, just as an excess of food injures animals. Those who imagine that the advantage of drainage arises from the removal of stagnant water, or any such cause alone, overlook the great and important fact that *drained land is, in summer, from* 10° *to* 20° *warmer than water-logged land.* Professor Schubler long ago came to the conclusion that the loss of heat caused by evaporation in undrained lands amounted to 11¼° to 13½° Fahr. Mr. Parkes has shown, in his "Essay on the Philosophy of Drainage," that in draining the Red Moss near Bolton-le-Moors, the thermometer in the drained land rose in June, 1837, to 66° at seven inches below the surface, while in the neighbouring water-logged land it would never rise above 47°, an enormous gain. In the garden of the Horticultural Society the mean temperature of the thoroughly drained soil at one foot below the surface is, in the month of July, 63°49; if we take that of water-logged land to be the same as spring water, or 47°, there is a gain of 16½°. Thus it

is evident that drainage produces the very important effect upon land of raising its temperature; it communicates bottom heat, in the absence of some amount of which, even the common Nettle and Groundsel would perish; and as scarcely any of our cultivated crops are natives of countries so cold as our own, it is manifest that they all require to have the earth warmed for them, or are much the better for it.

The reason why drained land gains heat, and water-logged land is always cold, consists in the well-known fact that heat cannot be transmitted *downwards* through water. This may be readily seen by the following experiments:—

EXPERIMENT No. I.—A square box was made of the form represented by the annexed diagram, eighteen inches deep, eleven inches wide at top, and six inches wide at bottom. It was filled with peat saturated

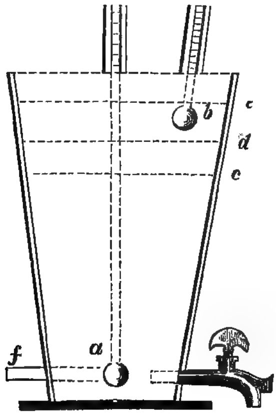


Fig. XXVII.

with water to *c*, forming, to that depth (twelve and a half inches), a sort of artificial bog. The box was then filled with water to *d*. A thermometer (*a*) was plunged so that its bulb was within one and a half inch of the bottom. The temperature of the whole mass of peat and water was found to be 39½° Fahr. A gallon of boiling water was then added; it raised the surface of the water to *c*. In five minutes the thermometer *a* rose to 44°, owing to conduction of heat by the thermometer tube, and its guard. At ten minutes from the introduction of the hot water the thermometer *a* rose to 46°, and it subsequently rose no higher. Another thermometer (*b*), dipping under the surface of the water at *e*, was then introduced; and the following are the indications of the two thermometers at the respective intervals, reckoning from the time the hot water was supplied:

	Thermometer *b*.	Thermometer *a*.
20 m.	150°	46°
1 h. 30 m.	101	45
2 h. 30 m.	80½	42
12 h. 40 m.	45	40

The mean temperature of the external air to which the box was exposed during the above period was 42°; the maximum being 47° and the minimum 37°.

EXPERIMENT No. II.—With the same arrangement as in the preceding case, a gallon of boiling water was introduced above the peat and water, when the thermometer *a* was at 36°; in ten minutes it rose to 40°. The cock was then turned for the purpose of drainage, which was but slowly effected, and at the end of twenty minutes the thermometer *a* still indicated 40°; at twenty-five minutes 42°, whilst the thermometer *b* was 142°. At thirty minutes the cock was withdrawn from the box; and more free egress of water being thus afforded, at thirty-five minutes the flow was no longer continuous, and the thermometer *b* indicated 48° The mass was drained and permeable to a fresh supply of water.

Accordingly another gallon of boiling water was poured over it and in

3	minutes the thermometer *a*		rose to	77°
5	,,	,,	fell to	76½
15	,,	,,	,,	71
20	,,	,,	remained at	70½
1h. 50	,,	,,	,,	70½

In these two experiments the thermometer at the bottom of the box suddenly rose a few degrees immediately after the hot water was added; and hence it might be inferred that heat was carried downwards by the water. But in reality the rise was owing to the action of the hot water on the thermometer, and not to its action upon the cold water. To prove this, the perpendicular thermometers were removed. The box was filled with peat and water to within three inches of the top; a horizontal thermometer (*a f*) having been previously secured through a hole made in the side of the box by means of a tight-fitting cork, in which the naked stem of the thermometer was grooved. A gallon of boiling water was then added. The thermometer, a very delicate one, made by Newman, was *not in the least affected* by the boiling water in the top of the box.

In this experiment, the wooden box is a field; the peat and cold water represent the water-logged portion; rain falls on the surface and becomes warmed by contact with the soil and thus heated descends. But it is stopped by the cold water, and the heat will go no further. But if the soil is drained and not water-logged, the warm rain trickles through the crevices in the earth, carrying to the drain-level the high

temperature it had gained on the surface, parts with it to the soil as it passes down, and thus produces that bottom heat which is so essential to plants, although so few suspect its existence.

This necessity of warmth at the root undoubtedly explains in part why it is that hardy trees, over whose roots earth has been heaped or paving laid, are found to suffer so much, or even to die; in such cases, the earth in which the roots are growing is constantly much colder than the atmosphere, instead of warmer.

It is to the coldness of the earth that must be ascribed the common circumstance of Vines that are forced early not setting their fruit well, when their roots are in the external border and unprotected by artificial means; and to the same cause is often to be ascribed the *shanking* or shrivelling of grapes, which most commonly happens to Vines whose roots are in a cold and unsunned border.

Mr. Knight long since mentioned an important fact connected with this subject:—"It is well known," he said, "that the bark of Oak-trees is usually stripped off in the spring, and that in the same season the bark of other trees may be easily detached from their alburnum, or sap-wood, from which it is, at that season, separated, by the intervention of a mixed cellular and mucilaginous substance; this is apparently employed in the organisation of a new layer of fibre, or inner bark, the annual formation of which is essential to the growth of the tree. If, at this period, a severe frosty night or very cold winds occur, the bark of the trunk, or main stem, of the Oak-tree becomes again firmly attached to its alburnum, from which it cannot be separated till the return of milder weather. Neither the health of the tree, nor its foliage, nor its blossoms, appear to sustain any material injury by this sudden suspension of its functions; but the crop of acorns invariably fails. The Apple and Pear-trees appear to be affected to the same extent by similar degrees of cold. Their blossoms, like those of the Oak, unfold perfectly well, and present the most healthy and vigorous character; and their pollen sheds freely. Their fruit, also, appears to set well; but the whole, or nearly the whole, falls off just at the period when its growth ought to commence. Some varieties of the Apple and Pear are much more capable of bearing unfavourable weather than others, and even the Oak-trees present, in this respect, some dissimilarity of constitution." (*Hort. Trans.*, vi. 229.)

It is also the coldness of the soil which causes the production of roots upon the stems of the Vine in a hot damp Vinery;

which diminishes or prevents colouring; which renders it impossible to ripen wood; and which deteriorates the quality of the Grape. Hence all good Vine-growers now look more to the temperature of their borders than to its mechanical condition.

The Formation of Aerial Roots by Vines is an unmistakeable sign of the coldness of the border. Vineries may be seen with these roots hanging down like beards from the branches; and these are always followed by bad grapes, unless means are taken to heat the border. The explanation of the phænomenon seems to be this:—

The Vine possesses a very strong vegetating power, which is manifested whenever sufficient heat and moisture are present. It is also well known that if one portion or shoot of a Vine-plant is introduced to an atmosphere congenial to its growth, the buds will push into foliage and shoots; whilst the rest of the plant, exposed to cold, will not be perceptibly affected, and will contribute nothing to the active vegetation of the branch introduced to heat and moisture. According to circumstances, therefore, vegetation may be active in one part, and at the same time comparatively dormant in another part of the same Vine-plant. If the natural roots are dormant owing to the low temperature to which they are exposed, then unnatural roots will be formed by branches if in a state of growth. Moisture favours the formation of these roots; they shrivel in hot dry weather, but push again on the return of a dull or moist state of the atmosphere. They arise from the shoots being in a highly favourable situation for growth, and the roots in the reverse. The leaves elaborate a quantity of sap proportionate to their size, and to the share which light has had in perfecting their development. Part of this elaborated sap is appropriated by the above-ground portion of the plant. But in ordinary cases, and more especially where a vigorous growth is promoted, there is always a surplus beyond what the stem and its dependencies above ground require, and the proper destination of this is the roots, in order that their increase may correspond with that of the plant above them. But roots in a border five feet deep, and of a clayey nature, will be in a temperature little above 40° early in spring. At about 40° water has its greatest density. Under such circumstances any movement in the fluids of the roots must be extremely sluggish; and were these roots as open to observation as the stem is, there is no doubt they would be found as dormant as a shoot left outside in the cold, compared with another introduced to the heat of a forcing-house. When the roots of Vines are healthy, in proper soil sufficiently warm, their growth proceeds in due proportion to that of the top, but if they are badly conditioned, they can neither act their part nor appropriate their share of the returning juices; consequently an accumulation of the latter takes

place in the stems, and, favoured by the moist warm atmosphere of the Vinery, bursts through the bark in the form of fibres, continuing to lengthen till they are checked by drought. An extraordinary production of these aërial roots was observed to take place whilst an experiment was being made with a Black Hamburgh Vine, in the garden of the Horticultural Society. It had grown vigorously in an open border, when, being in freedom, no rootlets broke from the shoots. A 3-light frame was placed over this plant, and made as air-tight as possible; the sashes were never opened, except to supply water to the roots; a thermometer inside the frame was generally raised every day above 140° by sun heat. An Orchid placed in a shaded part of the frame was killed in two days, yet the Vine continued to grow. It burst its winter buds rapidly into shoots, and almost as soon as the buds on these young shoots were formed, they also pushed, weaker of course, and again still weaker growths proceeded from these secondary shoots. Meanwhile a vast number of roots issued from the shoots trained horizontally near the glass, and these roots soon reached the surface of the ground, which became matted by them, for it was moist, and for a little way sufficiently warm, by reason of the sun-heated air in the frame. But with regard to the old roots in the earth, the case was very different. The heated air of the frame could but slightly affect the soil at the depth where they were situated, whilst those extending beyond the limits of the frame were of course entirely beyond its influence.

The consequences of a profusion of branch-roots on the Vine are these; they absorb moisture from the air in the house, and so tend to increase the breadth of the foliage and swelling of the berries; even the thickness of the wood is considerably increased by them, for it is not uncommon to see a Vine branch smaller at the base than higher up; in short they are sources for the supply of nourishment, but they are *sources which dry up when they are most wanted.* They assist in forming a widely expanded foliage during moist weather; and when dry weather demands a greater supply, to compensate for increased evaporation from broad foliage, the stem-borne rootlets contribute nothing. To their precarious supply may be partly attributed the shanking and shrivelling of fruit. They should be checked in time by allowing the air in the house to become occasionally dry. But above all things, their appearance should be prevented by maintaining a due proportion between the temperature of the air and earth in which the Vines are plunged.

The effect of ARTIFICIALLY WARMING A VINE BORDER in this country has been seen in many instances; not the least instructive of which occurred to Mr. Purday, the eminent and scientific gunsmith. In his garden at Bayswater, a Vinery was filled with wood and produced an abundance of excellent Grapes in little less than two years, by merely

warming the border. The first year the Vines made wood thirty-seven feet long, strong, short-jointed and *well ripened.* But the plan was carried out still better at Castle Malgwyn, near Pembroke, the seat of A. L. Gower, Esq., by Mr. Hutchinson, who has described it in the *Journal of the Horticultural Society.* "The bottom of the border," he says, "is gently sloped from the houses to the extreme edge, where is built a box-drain extending the whole length of the border, as shown in the accompanying section marked 1; this drain is one foot square, the top of it being level

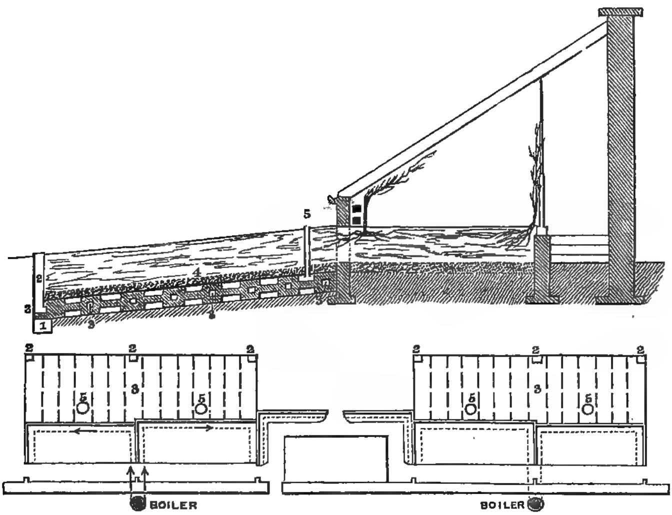


Fig. XXVIII.—Ground plan of houses, showing cross walls beneath the Vine borders.

with the bottom of the border, as also shown in section. When this was completed dwarf walls, marked 3, were built across the border, three and a half feet apart, one foot square, in the pigeon-hole manner: on the top of these walls are laid rough flags; these in reality form the bottom of the border, and upon these is placed about six inches of broken stones and bricks, marked 4, then covered with turf with the grassy side down, to prevent the soil mixing with the stones. There are flues or chimneys at each end of the border and centre communicating with the drains in the bottom, as shown in section marked 2. The top of these flues is nicely made of stone ten inches square, through which is cut a hole of six inches square, into which is inserted a plug of a wedge-like form, so as to fit tightly, but removeable at pleasure; these flues are about an inch above ground. At the back of the border are placed cast-iron pipes (marked 5), perpendicularly, and also communicating

with the drains underneath; those being higher than the flues in front cause a motion in the air beneath the border. After a long continuance of rain the plugs in the flues in front are taken out, thereby creating a great circulation of air, and thus to a vast extent accelerating the proper drying of the borders, which is deemed of much importance. In the winter season the borders are covered with leaves and stable manure to the depth of twelve inches. It is obvious that the whole aim of the constructor of this border was to do that which experience shows to be so important. He not only got rid of superfluous water, but he introduced air in abundance, and at the same time the natural warmth which it carries with it. The result was Black Hamburgh Grapes, *weighing from two pounds nine ounces up to five pounds a bunch*—beautiful fruit of admirable quality, on Vines just seven years old.

The experiments with CONCRETING VINE BORDER, were all made with the same end in view, namely, the elevation of the temperature of the soil in which Vine roots are formed. By keeping them near the surface, they derive much more advantage from the sun than if they penetrated deeply into the ground, which a concrete bottom renders impossible. Mr. Fleming, the experienced gardener at Trentham Hall, in Staffordshire, found it impossible to obtain good Grapes in that cold soil until the plan of concreting was employed. As soon as the bottom of his border was artificially rendered impenetrable by the Vine roots, all difficulty disappeared. In illustration of the effect of the system he mentions in the *Gardener's Chronicle* for 1850, p. 723, the following circumstance. In one of the houses which had been planted eight years, the black Grapes ceased to colour well; and as the border was well made, and rested upon well prepared concrete, having a declivity to throw off the wet quickly, he was much disappointed. Upon opening the ground in front of the border, the cause of the Grapes not colouring was immediately discovered; the roots had got into the drain, and across it into the subsoil beyond the concrete.

Mr. Spencer, of Bowood, one of the most experienced and perfectly well informed of all our great English gardeners, has carried out the plan of concreting in a different manner, of which he has given an account,* which contains so much practical wisdom that it is here republished with little curtailment.

"On many descriptions of soils, the Vine grows with great vigour, and will bear large crops of fruit, with but little or no assistance in the way of manure—such appears to be the case with the one at Cumberland Lodge,† the Hampton Court Vine, and others in various places.

* See *Gardener's Chronicle* for 1850, p. 772.

† The following is the history of the great Vine at Cumberland Lodge, in Windsor Park, which is alluded to by Mr. Spencer. It was planted about fifty years ago, in common light garden soil resting upon a bed of hard gravel and clay. In 1850 it produced

The two Vines in question both grow on shallow rich soils, the one at Cumberland Lodge being a light sandy loam resting on the gravel and clay of the London basin, while at Hampton Court it is a finely divided alluvial soil resting on gravel, the subsoil in both cases being dry and compact. Such being the case, it matters little what the material consists of, for a clay bottom may be equally good with a gravel one if drained naturally by fissures, or other causes. In such situations the Vine finds all the elements it requires for its growth. The fertilising particles of matter are equally distributed through the soil. There is no disposition in any portion of such soils to run together, or to become sour; every facility is afforded the roots to permeate the earth, while the finely divided state of the various ingredients composing them (and their perfect admixture) favours the production of those minute fibrous roots (never found on strong heavy soils) which are so essential an element of success in Grape growing. Here, then, is all the Vine requires to produce good and abundant crops, and to form for itself a constitution enabling it to supply generations with its generous produce. I am not aware of any peculiarity in the loams resting on the London clay (such are, however, much the best for all descriptions of potting) except it be in the finely divided state of the parts composing them, and the presence of rich calcareous matter; but I have seen the Vines growing on similar soils in Hampshire with much freedom, and ripening out of doors fruit in good perfection. Again, on the southern slopes of the hills near Bath the Vine grows vigorously in the natural soil, though the oolite rocks on which the surface soil rests is much colder than either a gravelly or a well-drained clay one. Many of these soils are rich in potash, from being more or less mixed with portions of the fuller's-earth beds. The best natural soils for the Vine are those formed by the decomposition of volcanic rocks, such being invariably of a dry, porous quality, and are rich in inorganic matter. Such being the nature of the soils on which the Vine thrives in the greatest perfection, it would be supposed that in the formation of borders expressly for its growth, some approximation would be made towards them by making the borders for the most part, if not all, of the same constituents; or in other words, forming "*a warm, light, dry, shallow soil.*" In place of this, however, much labour and expense have been incurred in making borders, in which the Vine refuses to thrive at all. What I may term artificial Vine borders are generally composed of various ingredients, of which loam, dung, and some dry material, as brickbats, mortar, rubbish, &c., may be considered as the principal. To these some add carrion, or other similar substances. Now we will suppose these materials to be

two thousand large bunches of magnificent Grapes, filled a house one hundred and thirty-eight feet long and sixteen feet wide, and had a stem two feet nine inches in circumference. The border in which it grows is *warm*, *light*, *dry*, and *shallow*.

the best of their kind, that they have been properly mixed and prepared, and that the border has been made, and the Vines planted, in the usual way. There can be no question but that (if other things are favourable), on a border of this description, the Vine will grow vigorously, and mature fine crops of Grapes. But let us wait some eight or ten years, when the fibre of the loam is rotted, and its elasticity destroyed, by which time the dung has become a sour pasty mass; while the rain during that period will have washed down the more soluble parts, and will have partially, if not totally, stopped the natural drainage. If at the same time the loam has been somewhat of a heavy texture, the evil will be increased. In fact, it will be found, on examination, that what was, for the first few years, a rich porous border, has become, through causes perfectly natural, unsuited for the growth of the Vine.

"I consider that when healthy and permanent Vines are wished for, more loam, and that of a sandy nature, should enter into the composition of Vine borders, and that a large portion of the following should be intimately incorporated with it, viz., charcoal dust, charred matter, wood ashes, and soot. What manure is used should be perfectly rotten, and as dry as can be procured, and that road scrapings, or (what is better) the sweepings of large towns, well rotted, and mixed with the above, will be found one of the best materials for a sound healthy border.

"In preference to concreting the bottom, I would recommend the border to rest on any description of rough paving stones, raised on rough walls, one foot or more, according to the situation, thus forming a series of air drains under the border, the outlet to which may either be in the house, or in some place enabling you to connect them with the external air. With a bottom of this description I would then certainly concrete the surface. I use gravel, lime, and coal ashes made into mortar, and spread two inches thick; in addition, when the above is dry, it gets a coat of gas tar over the surface; this forms a compact substance, treading firm underfoot, and effectually throwing off rain; common 3-inch draining pipes are placed upright in the border previously, which stand one inch above the surface when the concrete is laid on. When it is necessary to water the border, it can be done to any extent by pouring water down the pipes. In winter, all agree the drier the border the better; and plugs are then placed in them. It will, however, be found that less water will be required than might be expected, arising from the obstruction to free evaporation by the concrete. In a small Vinery, planted in August, 1848, the border of which was concreted after planting, I have only watered the outside border once (the inside border being only two feet wide), and yet the Vines have never shown the least indications of having required more, irrespective of the advantage of having in our

climate the roots of the Vine under control as respects moisture. Another point gained by concreting is the additional heat the border gains by the absorption of solar heat. I have proved frequently that a border, concreted as I have described, obtains an increase, at twelve inches deep, of from twelve to fifteen degrees, and even more during hot sunshine. This increase of heat on the surface of the border will have the effect of causing that part of the border to be the dampest, as it will be the warmest; the roots accordingly will be more numerous immediately under the concrete, and precisely in that position most favourable for their healthy development. An additional advantage of the concrete is its preventing the border becoming compact, from walking over it, and consequently its porosity is preserved. I say nothing of the disadvantage ascribed to it, from its supposed prevention of atmospheric air to the border, because I believe the thing impossible; and on the principles described above, air has access at all times underneath the border, if it is required, which I believe it is not. It certainly looks somewhat unsightly during summer, but a few pots of flowering plants set on it during summer, and a slight coat of Fern or thatch during winter will do away with its formal appearance."

This plan of concreting the surface is, as will have been seen, intended to increase the temperature of the Vine border. In order to secure all the advantages of the method without any disadvantages, it seems essential that the border should rest upon rough materials, so put together that air can readily find its way upward through them into the border. Mr. Spencer's border rests on rough paving-stones raised on rough walls, and is then connected with the external air or with that of the Vinery itself. Under such circumstances, air will find its way to the roots more readily than by any other known method; and thus the conditions demanded in a perfect Vine border, viz., warmth, dryness in winter, and damp in summer, with permeability at all seasons, are perfectly fulfilled. That the raising the border on a vaulted bottom is of very great value, concrete or no concrete, is admitted by the best Grape growers. Mr. Hutchinson's borders at Castle Malgwyn are so managed; and the early houses at Trentham, built under Mr. Fleming's direction, have borders of the same kind. We would not, however, be understood to say that these contrivances are at all times necessary. On the contrary, when soil and situation are naturally suitable to the Vine, very fine Grapes are obtained without any such aids. The important point is, how to deal with this valuable fruit-tree when, as so often happens in Great Britain, the soil and situation are *unfavourable;* and that can be only accomplished by securing a sufficient amount of bottom heat.

Mr. Reid, of Balcarras, has shown that one of the causes of canker and immature fruit, even in orchards, is the coldness of

the soil. He found that, in a cankered orchard, the roots of the trees had entered the earth to the depth of three feet; and he also ascertained that, during the summer months, the average heat of the soil, at six inches below the surface, was 61°; at nine inches, 57°; at 18 inches, 50°; and at three feet, 44°. He took measures to confine the roots to the soil near the surface, and the consequence was, the disappearance of canker, and ripening of the fruit. (*Memoirs of Caledonian Hort. Soc.*, vi., part 2; and *Gardener's Magazine*, vii. 55.) The same fact has been observed in many other instances.

If, on the other hand, we take cases of growth in the artificial climate of hot-houses, we find that Bignonia venusta, and many other tropical plants, will not flower, unless in a high bottom heat; and that Palm-trees, planted in the soil of conservatories which it is impracticable to heat sufficiently, soon become unhealthy.

The reason why it is necessary to plants in a growing state, that the mean temperature of the earth should be higher than that of the air, is sufficiently obvious. Warmth acts as a stimulus to the vital forces, and its operation is in proportion to its amount, within certain limits. If, then, the branches and leaves of a plant are stimulated by warmth to a greater degree than the roots, they will consume the sap of the stem faster than the roots can renew it; and, therefore, nature takes care to provide against this by giving to the roots a medium permanently more stimulating, that is, warmer, than to the branches and leaves.

We regard warmth not merely as a stimulus of vegetation; it is extremely necessary for the solution of various substances with which the water comes in contact. It also sets free certain gases which the leaves take up, and through these sources of nourishment promotes the growth of plants.—*German Ed.*

Such being the fact, it is obvious that one of the first of a gardener's cares should be, to secure the means of insuring a proper temperature to the soil in which he grows his plants, and that this is requisite for hardy as well as tender species.

I entertain little doubt that the time is at hand when it will be considered quite as necessary to furnish heat for the soil as for the air; not, however, heat without moisture, for that would evidently produce much greater evils than it was intended to cure, as has indeed been found by inconsiderate experimenters. Mr. Writgen is probably right in believing that it is the temperature and moisture of a soil quite as much as its mineralogical quality, that determine its influence upon vegetation. (See *Erster Jahresbericht, &c., am Mittel und Nieder-Rhein*, p. 64.) It must not, however, be supposed that the nature, whether chemical or physical, of soil is unimportant. A crop of wheat cannot be had on peat, nor will salt plants thrive when the soil contains no marine salt.

Mr. Fintelmann, the king of Prussia's gardener at Potsdam, is celebrated for his success in the difficult art of forcing Cherries, and he has given an account of his practice (*Gard. Mag.*, vol. iii., p. 64), in which it appears that the most peculiar feature is the strict attention he pays to the temperature of the roots. He first soaks the roots in water heated by the mixture of equal parts of boiling and cold water; he afterwards sprinkles the trees with luke-warm water, and he continues to employ it of the same temperature as long as watering is required. Thus his roots are constantly maintained at the requisite temperature by the trickling of the warm water into the soil.

It seems, indeed, clear, that the success of the Dutch in obtaining an abundance of fresh vegetables, such as Lettuces, during the whole winter, is in part owing to their being able to maintain a gentle bottom heat. No doubt this is connected with the abundant light which their forcing structures admit, and with other causes of considerable importance, such as an abundant, constant, and skilful introduction of fresh air; but none of those causes can be supposed likely, in the absence of the bottom heat, to produce such a result as the Dutch gardeners obtain.

If it is necessary that the temperature of the *soil* in which plants grow should be carefully regulated, and adjusted to their natural habits, it is no less requisite that the *water* in which

aquatics are cultivated should be also brought to a fitting heat. Mr. William Kent succeeded well in making many tropical species flower, by growing them in lead cisterns plunged in a tan-bed (*Hort. Trans.*, iii. 34) in a close heat. In like manner, Mr. Christie Duff procured flowers in abundance from Nymphæa rubra, cærulea, and odorata, by placing them in a cistern in a pine stove upon the end flues, where the fire enters and escapes; or by plunging them into tan-beds in pine-houses, varying in temperature from 80° to 100°. (*Hort. Trans.*, vii. 286.) Very lately, Mr. Sylvester, of Chorley, in Lancashire, obtained fine flowers from Nelumbium luteum, by paying attention to the temperature of the water. When he kept the latter at 85°, the plants grew vigorously, and were in perfect health, but flowerless; but by lowering it to 70°—75°, which more nearly approaches the heat to which the plant is naturally accustomed, the magnificent blossoms were produced and succeeded by seeds; the red Nelumbium, however, which inhabits countries with a greater summer heat than the yellow, at the same time suffered by this lowering of temperature, none of its blossom buds having been able to unfold. (*Bot. Mag.*, xiii., n. s. t. 3753.) The water of rice fields, in which the red Nelumbium flourishes, was seen by Meyen at 113° at Lantao, in China.

The Victoria Lily affords another instance. It will grow while its roots are in a temperature wholly insufficient to enable it to flower. And another water plant, the Aponogeton distachyum, flowers abundantly even in winter wherever the temperature of the pond in which it grows rises sufficiently.

Well-regulated bottom heat being thus shown to be of such immense importance in gardening, it is surprising that more attention should not be paid to economising the waste water of steam engines where factories are conveniently situated. What may be done, without cost, by attention to this, is shown by the following experiment tried by Mr. Dillwyn Llewellyn, of Penllergare. From a small eight-inch cylinder engine, employed by him for agricultural purposes, this gentleman conducted a jet of steam for twenty minutes daily, through an inch iron pipe, into a bed of rough stones, covered by a glazed frame. A journal of the temperature was kept for eleven days, with the following result:—

STATEMENT OF EXPERIMENT WITH WASTE STEAM, AS A MEDIUM OF BOTTOM HEAT, MADE AT PENLLERGARE, 1850.

Date.	Time of Observation.	Thermometer.	
April.		Degrees.	
9	12 Noon	51	Steam introduced about 12 o'clock.
,,	5 P.M.	54	
,,	7 P.M.	56	
10	12 Noon	68	Steam introduced.
,,	3 P.M.	73	
,,	5 P.M.	85	
,,	7 P.M.	96	
11	7 A.M.	108	Steam not introduced.
,,	12 Noon	104	
,,	5 P.M.	98	
12	10 A.M.	83	Steam not introduced.
,,	7 P.M.	79	
13	10 A.M.	69	Steam introduced.
,,	6 P.M.	75	
14	10 A.M.	82	Steam not put on.
,,	7 P.M.	79	
15	10 A.M.	70	Steam introduced.
,,	6 P.M.	73	
16	10 A.M.	81	Steam introduced.
17	10 A.M.	76	Steam introduced.
,,	4 P.M.	79	
18	10 A.M.	94	Steam introduced.
,,	5 P.M.	110	
19	10 A.M.	108	Steam not introduced.
,,	6 P.M.	96	

From this it appears, 1st, that although steam was introduced among the stones for only twenty minutes a day, the temperature was raised from 51° to 68° in the first twenty-four hours; 2nd, that the temperature continued to rise for many hours after the second application of steam, until the thermometer reached 108°; 3rd, that at the end of nineteen hours the heat of the frame diminished; yet 4th, that at the end of *seventy hours* the temperature still was 69°. This appears a conclusive answer to those who think that masses of heated water, or heated porous materials, like rough stones, will become so reduced in temperature by a few hours' withdrawal of the prime heating power as to endanger the plants cultivated in houses thus warmed. The experiment continued to be successful, and enabled Pine-apples of the most perfect quality to ripen.

An opinion has, nevertheless, been entertained, that bottom heat is useless; there is in the *Horticultural Transactions*, (vol. iii. 288) a paper to show that it is injurious; and the authority of Mr. Knight has been referred to in support of the opinion, in consequence of that great horticulturist having expressed a belief that the "bark-bed is worse than useless." (*Hort. Trans.*, iv. 73.) But Mr. Knight repeatedly disavowed entertaining any such sentiments. In one place, he stated that the temperature of the air of the stoves in which his Pine-apple and other stove plants grew, *without bark or other hot-bed,* usually varied from 70° to 85°; and that the mould in his pots, being surrounded by such air, acquired and retained, as it necessarily must, very near the same aggregate temperature, but subject to less extensive variation (*Gard. Mag.*, v. 365): in another, he says the temperature of the air was varied in his stove generally from about 70° to 85° of Fahrenheit; and he ascertained, by keeping a thermometer immersed in the mould of the pots, that the temperature of the soil varied very considerably less than that of the air of the stove; the mould being in the morning generally some degrees warmer than the air of the house, and in the middle of the day, and early part of the evening, some degrees cooler. (*Hort. Trans.*, vii. 255.) It is, therefore, clear that he considered a high temperature necessary for the roots of his Pine-apple plants; and we find from one of his papers (*Hort. Trans.*, iv. 544), that he considered it better to obtain the requisite temperature from the atmosphere than from a bark-bed, the usual source of bottom heat, "because its temperature is constantly subject to excess and defect;" and he even admitted that if the bark-bed could be made to give a steady temperature of about 10° below that of the day temperature of the air in the stove, Pine plants would thrive better in a compost of that temperature than in a colder. The dispute about bottom heat was not as to the necessity of it, but as to the manner of obtaining it, which, as it concerns the *art* of gardening, I need not further notice.

We have, doubtless, much to learn as to the proper manner of applying bottom heat to plants, and as to the amount they will bear under particular circumstances. It is, in particular,

probable that in hot-houses plants will not bear the same quantity of bottom heat as they receive in nature, because we cannot give them the same amount of light and atmospheric warmth; and it is necessary that we should ascertain experimentally whether it is not a certain proportion between the heat of the air and earth that we must secure, rather than any absolute amount of bottom heat.

It may also be, indeed it no doubt is, requisite to apply a very high degree of heat to some kinds of plants at particular seasons, although a very much lower amount is suitable afterwards; a remark that is chiefly applicable to the natives of what are called extreme climates, that is to say, where a very high summer temperature is followed by a very low winter temperature. Such countries are Persia, and many parts of the United States, where the summers are excessively hot, and the winter's cold intense. The seeming impossibility of imitating such conditions artificially will probably account for many of the difficulties we experience in bringing certain fruits, the Newtown Pippin, the Cherry, the Grape, the Peach, and the Almond, to the perfection they acquire in other countries.

The great point to attend to in these considerations is the extremes of temperature to which plants are subject when growing; for this reason the calculations of M. Boussingault have less value than might have been anticipated. This distinguished French writer upon rural economy proposed, some years ago, a method of determining what amount of HEAT a plant requires, in order to be enabled to perform the functions allotted to it by Nature. This method consisted in determining the length of time over which a function extends, and also the mean temperature during that period. Thus, if a given plant requires 20 days to ripen its seeds after flowering, and the mean temperature during that time was 10°, it would be assumed that the plant in question requires 200° of heat to complete the ripening process. Or if the period occupied was 10 days, and the mean heat 10°, then only 100° of heat would be required, and so on. M. Boussingault's method was a great improvement upon the previous modes of computation. Observers had been previously contented with annual or quarterly, or other long

means of temperature, as furnishing the elements required to determine whether a given plant could be advantageously cultivated in a given country. But these means were all more or less fallacious, and might have led to serious mistakes. Mean temperatures are useless to cultivators unless they represent what takes place during the period of vegetation. We do not want to know what the temperature is of seasons when, or of places where, plants do not grow, unless for the purpose of determining the amount of winter protection which they may require; and all indications of climate in which the dormant season is mixed with the growing season only mislead. Suppose, for example, it was to be said that the mean annual temperatures of Longville and Bretville are the same (say 35°), this would be no proof of similarity of climate, for Longville might have the winter mean 20°, the summer mean 50°; while Bretville might have the winter mean 30°, and the summer mean 40°—cold winters and temperate summers characterising one place, mild winters and bad summers characterising the other. Nor are daily means much more useful. Let us suppose that Longville has in June a daily mean of 45°, while that of Bretville is 50°; it might be that these means represented hot days and cold nights in the one case, and cool days and mild nights in the other—conditions which for the purposes of cultivation are wholly different. That M. Boussingault's method of explaining the relation between plants and climate was an important improvement upon the usual indications is not to be denied. But it was not wholly satisfactory. Pushed to its limits the theory was manifestly untenable, for it amounted to this—that if a plant requires 20 days with 10° of heat in each day, or 200° to do a certain thing, and if it can do the same thing in 10 days, with 20° of heat in each day, then it ought to accomplish the same end in one day by the aid of 200° of heat, which is absurd.

In all considerations relating to ground temperature, the gardener should inform himself more especially upon three points:—1, the temperature of the soil when plants are at rest; 2, that when they are in vigorous growth; and 3, that when they are ripening their fruit. The first points out the bottom

heat to be maintained in winter, the second in summer, the third in autumn. Information upon this question can be had by consulting the tables of temperature published in the *Journal of the Horticultural Society*, vol. iv., and comparing them with the remarks at the pages following p. 113 of this work. In what way such evidence is to be practically employed will be seen in the succeeding table, calculated by Mr. R. Thompson, with a view to explaining what the natural temperature is to which certain plants commonly cultivated are exposed in the climates best adapted to their healthy development.

I.—A Table of Ground Temperatures natural to Certain Plants, as either actually observed, or calculated from known Air Temperature.

Name.	Most Suitable Climate.	Season of Growth.	Season of Ripening.	Season of Rest.
Apple, Pear, &c. . .	North of France	59	64	41
Peach and Nectarine .	Persia . . .	65	78	55
Apricot	Armenia . . .	57	72	27
Cherry	Asia Minor . .	56	68	43
Gooseberry, &c. . . .	Lancashire . .	54	61	44
Quince	Portugal . .	62	70	55
Vine, Muscats . . .	Sicily	66	80	55
,, Sweetwaters . .	Paris	58	66	41
Fig	Smyrna . . .	60	80	46
Melon	Smyrna . . .	60	80	
Plantain, or Banana .	Jamaica . . .	82	88	80
Pine-apple	Surinam . . .	82	88	81
Mango	Bengal . . .	85	89	83
Vanilla	Surinam . . .	82	88	81
Orange	Malta	60	77	56
Mangosteen	Malacca . . .	84	86	81
Loquat	Japan	70	80	49
Litchi	Canton . . .	74	86	59
Oats	Scotland . . .	51	57	41
Barley	England . . .	54	62	42
Wheat	Castile . . .	61	78	46
Maize	Virginia . . .	70	79	
Rice	Bengal . . .	89	92	

II.—A Table of the ascertained, or estimated Average Ground Temperatures in different Parts of the World.

Country.	Season of Growth.	Ripening.	Rest.
London (Chiswick)	55	62	42
Africa, South (Cape of Good Hope)	62	67	58
,, ,, (Graf Reynet)	65	74	58
Algiers	66	76	57
,, (Constantine)	66	82	49
Amsterdam	57	64	40
Armenia (Erzeroum)	57	72	27
Astrachan	56	74	23
Australia (Coburg Peninsula)	83	85	80
,, (Port Jackson)	67	75	58
,, Western (Perth)	67	81	59
Ava	79	88	68
Azores (St. Michael's)	65	68	60
Batavia	82	83	80
Benares	84	91	67
Berlin	59	64	36
Berne	49	59	33
Beyrout	65	79	59
Bogota	64	64	62
Bombay	84	87	82
Brussels	59	65	41
Bucharest	58	65	30
Cairo	70	87	62
Calcutta	82	90	75
Canada (Toronto)	58	66	30
Canton	74	84	57
Caraccas (Maracaybo)	87	89	86
Ceylon (Badulla)	73	75	71
,, (Candy)	75	78	74
Constantinople	64	73	44
Dantzic	54	64	30
Dublin	56	60	44
Edinburgh	51	57	41
Falkland Islands	49	56	42
Florence	64	76	44
Fort Vancouver	54	65	41

TABLE OF AVERAGE GROUND TEMPERATURES—*continued.*

Country.	Season of Growth.	Ripening.	Rest.
Geneva	58	70	33
Genoa	65	76	51
Guatemala	70	72	70
Guinea	86	87	84
Havannah	80	83	77
Himalayas (Khasia)	78	85	64
Hobart Town	53	62	44
Honolulu	77	80	74
Illinois (St. Louis)	65	77	34
Jamaica (Kingston)	82	88	80
Java (Buitenzorg)	80	81	79
Jerusalem	65	76	52
Lima	75	82	70
Lisbon	64	71	56
Liverpool	54	62	44
Macao	72	85	60
Madeira (Funchal)	65	74	67
Madras	85	88	83
Madrid	61	78	46
Manilla	78	90	74
Melbourne	60	65	51
Mexico	64	67	58
Montpellier	65	74	46
Montreal	65	72	25
Moscow	57	65	24
Munich	59	64	33
Naples	64	76	50
New Orleans	76	84	56
New York	64	72	36
New Zealand (Auckland)	59	66	53
Nova Scotia (Halifax)	50	69	25
Niger	88	91	84
Ootacamund	63	66	56
Oran	66	75	53
Oregon (Columbia)	65	75	41
Palermo	66	80	55
Paris	58	66	41
Penzance	56	63	47

TABLE OF AVERAGE GROUND TEMPERATURES—*continued.*

Country.	Season of Growth.	Ripening.	Rest.
Persia (Bushire)	79	90	64
Persia (Mosul)	65	93	48
Polynesia (Raiatea)	81	84	79
Quebec	58	71	20
Quito	64	66	63
Rio Janeiro	77	84	74
Rome	64	76	49
St. Petersburg	45	60	25
Sebastopol	60	70	39
Shanghae	73	80?	49
Sincapore	84	85	83
Surinam (Paramaribo)	82	88	81
Teflis	65	77	37
Trebizond	63	75	50
Trincomalee	84	88	80
Virginia (Norfolk)	68	80	48
Vera Cruz	81	86	74
Venice	60	74	40
Vienna	63	69	34
Washington	60	77	34

The temperature here estimated as that of the season of rest is to be understood as what roots are probably exposed to at a foot below the surface. Of course, upon the surface, the temperature would be lower.

CHAPTER II.

OF THE MOISTURE OF THE SOIL.—WATERING.

It has already been shown that water is one of the most important ingredients in the food of plants, partly from their having the power of decomposing it, and partly because it is the vehicle through which the soluble matters found in the earth are conveyed into the general system of vegetation. Its importance depends, however, essentially upon its quantity.

We know, on the one hand, that plants will not live in soil which, without being chemically dry, contains so little moisture as to appear dry; and, on the other hand, an excessive quantity of moisture is, in many cases, equally prejudicial. The great points to determine are, the amount which is most congenial to a given species under given circumstances, and the periods of growth when water should be applied or withheld.

When a plant is at rest, that is to say, in the winter of northern countries and the dry season of the tropics, but a small supply of water is required by the soil, because at that time the stems lose but little by perspiration, and consequently the roots demand but little food; nevertheless, some terrestrial moisture is required by plants with perennial stems, even in their season of rest, because it is necessary that their system should, at that time, be replenished with food against the renewal of active vegetation. Hence, when trees are taken out of the earth in autumn, and allowed to remain exposed to a dry air all the winter, they either perish, or are greatly enfeebled. If, on the other hand, the soil in which they stand is filled with moisture, their system is distended with aqueous matter at a time when it cannot be decomposed or thrown off, and the plant either

loses its roots by rotting, or becomes unnaturally susceptible of the influence of cold in rigorous climates, or is driven prematurely into growth, when its new parts perish from the unfavourable state of the air in which they are then developed. The most suitable condition of the soil, at the period of vegetable rest, seems to be that in which no more aqueous matter is contained than results from the capillary attraction of the earthy particles.

During the season of 1852 and 1853, in which rain fell, with little intermission, from November till March, and inundated permanently gardens in low situations, Rhododendrons, although fond of moisture, perished to a great extent. During winter they seemed to be healthy, but when spring arrived their leaves became dull, changed to brown, and withered, and the buds refused to push; or, when attempts were made by plants to renew their vegetation, their growth was feeble, and most of them died in the course of the following autumn or winter.

Nevertheless, there are exceptions to this, in the case of aquatic and marsh plants, whose peculiar constitution enables them to bear with impunity, during their winter, an immersion in water; and in that of many kinds of bulbs, which, during their season of rest, are exposed to excessive heat and dryness. The latter plants are, however, constructed in a peculiar manner; their roots are annual, and perish at the same time as the leaves, when all the absorbent organs being lost, the bulb cannot be supposed to require any supply of moisture, inasmuch as it possesses no means of taking it up, even if it existed in the soil.

The conditions under which true aquatics exist have been so well explained by a philosophical writer, in the *Gardener's Chronicle*, 1852, p. 19, that I quote his statement without curtailment, although his remarks, in part, refer to other questions besides the moisture of the medium in which roots are placed:—

Plants growing entirely under water are to some extent protected from those great and sudden changes of temperature to which ordinary land plants are frequently exposed; at the same time, however, water plants are very often injured by cold, and it not unfrequently happens, that on a cold winter's night plants in a pond will be greatly injured, or even killed, whilst those in a neighbouring pond will remain quite uninjured. In order to understand the precise cause of this phenomenon, we must examine the conditions under which plants grow, and the peculiar sources of injury to which they are consequently exposed.

There are three perfectly distinct modes in which the surface of the earth becomes cooled, and these are by evaporation, by conduction, and by radiation. When water evaporates it becomes colder, because, in the formation of vapour, heat is always absorbed. This simple fact is of the greatest importance to the life of both plants and animals. When plants are exposed to a hot sunshine, the moisture which they contain gradually evaporates, and in so doing absorbs the great heat of the sun's rays, which would otherwise injure plants and burn them up. Evaporation from the surface of the leaves is generally in proportion to the direct heat of the sun, and it is necessary as a means of keeping the plant cool, and preventing it from being scorched; if soil is dry, so that the plant cannot obtain, by means of its roots, a constant supply of moisture to keep up this daily evaporation from its leaves, it has no power of withstanding the heat of the sun, and it withers and fades the first hot day. Whenever, and in whatever manner, we check the constant evaporation which always goes on in the leaves of a healthy plant, we run a risk of killing it by exposure to hot sunshine. The common experience of the gardener gives plenty of examples of the truth of this; but there are other cases in which, though the same effect is produced, and the same principle is involved, its influence is not so self-evident. When, for example, a plant is placed in a close hothouse, confined in a hot damp air, its perspiration is checked, because the air being already saturated with moisture, it has little power of carrying off the moisture evaporated by the leaves, and consequently the plant has less power of withstanding the heating influence of the sun's rays than it has in the open air, or in a state of nature.

As evaporation, on the one hand, is a natural means of counteracting the excessive heat of the sun, so, on the other hand, it is the chief cooling agent in nature, and every circumstance tending to increase evaporation from the surface of the soil tends also to cool it. As a moist air and a diminished circulation are most unfavourable to evaporation, so a dry air and free circulation greatly facilitate it. The cooling effect of a cold dry wind is familiar to every one; its influence depends on the fact, that dry air readily absorbs moisture from any surface exposed to it, whilst the rapid motion of the wind, by carrying away the moisture as fast as it is formed, insures a constant supply of fresh dry air, and thus, by aiding in the formation of moisture, rapidly cools the surface on which it blows.

The second mode in which plants are cooled is by conduction, or by the mere contact of cold air; and this is quite independent of the cold produced by evaporation. When a cold wind drives along the surface of the ground it gradually cools it, and, of course, likewise the plants growing on it, by the simple abstraction, or carrying away of heat. So long as the surrounding air is colder than the plants it will tend to reduce their temperature; and if the air is in motion, as fresh portions

of cold air will continually come in contact with the plants, they must gradually get colder and colder, even though no evaporation takes place, till they are as cold as the air itself.

Radiation, the third mode in which plants are influenced by cold, depends upon the curious fact, that when two substances are placed opposite to each other in the free and open air, if the one is warmer than the other, it will immediately begin to give out its heat, which will be received by the colder substance. The difference between this mode of cooling and mere conduction is, that in the latter heat travels from the hot to the colder surface by contact, and therefore only when they absolutely touch each other, whilst in radiation, the two surfaces are at a distance, and the heat passes at once through the air, and without in any way warming it. The heat of the sun is radiant heat—it passes through the clear air without communicating any warmth to it, though it warms the earth below; and then when the sun's rays have warmed the earth, the latter in turn begins to warm the surrounding air—but this effect is no longer one of radiation, it is simply an effect of conduction. On a clear night the surface of the ground may be exposed to all three of these cooling influences at once; it may be cooled by evaporation, by contact with cold air, and by radiation. In reality, however, it is very seldom that all these cooling influences are in operation at the same time, because there are several counteracting powers at work tending to keep the surface of the soil at a tolerably uniform temperature; and foremost of these is the formation of dew. As the evaporation of water is a cooling process, heat being absorbed, so the condensation of moisture is a warming process, an equal amount of heat being given out; consequently, just in proportion as the surface of the earth after sunset is cooled by radiation, it will acquire the power of condensing the moisture in the air, and by that very act will gain heat. It must also be remembered that radiation only takes place in a still and clear night; when there are clouds or mist, radiation does not occur.

Water may be cooled either by evaporation, or by the contact of cold air, but it differs from the soil in the facility with which it is moved, and the readiness with which currents are formed in it. When the earth is exposed to cooling influences, the surface soon becomes cold, but as heat travels very slowly through the porous soil, it takes a very long time before the cold penetrates, or rather before the heat escapes from any depth below the surface; in the case of water it is quite different, because when the surface is in any way cooled, the water becomes heavier or denser, and a kind of circulation is immediately established, the cold water descending, and the warmer water rising to its surface. In this manner, then, so long as the cooling influences continue, the water goes on sinking in temperature, the whole body of it getting colder; this, however, does not continue after it has arrived

at a temperature of 40°, or about 8° above the freezing point; when this is the case, all circulation in the water ceases, because if the surface water is then cooled still lower, it no longer continues to contract and become denser, but on the contrary expands, so that it then remains floating on the surface. It follows from this very interesting fact, that when on a cold winter's night the surface of a pond is cooled, the whole body of water sinks in temperature to 40°, after that, the surface only continues to get colder, and a film of ice is soon formed, while the water below continues at a temperature of 40°. In consequence of this kind of circulation, and the facility with which it is produced, a body of water is easily cooled down to within 8° of freezing, but when once it has arrived at that point its further cooling proceeds very slowly, even though the cold becomes much more intense; for the water below is in fact protected from contact with the cold air by the film of ice at the surface, and ice is so bad a conductor of heat that the freezing of the water under the ice goes on very slowly; in temperate climates ice is seldom more than a few inches in thickness, and the water in deep ponds not only never freezes, but, indeed, never falls in temperature much below 40°.

Water plants, therefore, are, in fact, preserved from cold by the coating of ice which forms over the surface of the pond in which they grow; if the water is deep they are seldom injured; but if the water is shallow, and the cold long-continued, the whole depth of it will in time freeze, and the plants will be more or less injured. Plants growing in water thus walled over with ice are protected from all the three cooling influences to which we have alluded; but there are some circumstances under which water plants suffer greatly, and from a very singular cause, but one which, when looked into, is sufficiently simple and intelligible.

The surface of clear water does not become cold from radiation, but from contact with cold and dry air; consequently in a fine but very still night it is much less rapidly cooled than the earth, which, in addition, is exposed to the cooling influence of radiation. Under such circumstances it sometimes happens that the usual order of things is reversed, the bottom of the pond cooling more rapidly than the surface; on a clear still cold night radiation sometimes occurs from the bottom of a pond, the plants and soil in which they are growing radiating towards the sky just as if the water were not above them, and the consequence is that they become very cold, in fact, some degrees below the freezing point, though the water above them is still at 40°. This effect can only happen in clear water, and on a night when there are no clouds, for the same circumstances which prevent radiation from the surface of the ground will also prevent its taking place from the bottom of a pond. When plants under water are cooled by radiation, they soon become encased in ice, and though the ice thus formed generally melts the next

morning, yet at the time of its formation the plants are often exposed to a very intense cold.

A singular effect, somewhat similar in nature, though caused in a very different manner, is sometimes observed; as clear still water offers no obstruction to the passage of radiant heat, it occasionally happens that water plants are injured by the great heat of the sun's rays; like land plants they receive abundance of radiant heat from the sun, but, unlike land plants, they do not experience the compensating effect of evaporation; they only feel the less perfect cooling influence of the surrounding water. It therefore occasionally happens that plants growing in water, and surrounded by it, are burnt and scorched by the heat of the sun's rays, the radiant heat of which produces no effect on the water through which it passes, any more than it does in passing through the air; its effects only become evident when its rays fall upon a solid substance, such as the surface of the ground or the leaves of a plant.

It is when plants are in a state of growth that an abundant supply of moisture is required in the earth. As soon as young leaves sprout forth, perspiration commences and a powerful absorption must take place by the roots; the younger the leaves are, the more rapid their perspiratory action; their whole epidermis must, at that time, be highly sensible to the stimulating power of light: but as they grow older their skin hardens, the stomates become the only apertures through which vapour can fly off, and by degrees even these are either choked up, or have a diminished irritability. As a general rule, it is safe to conclude that the ground should be abundantly supplied with moisture when plants first begin to grow, and that the quantity should be diminished as the organization of a plant becomes completed. There are, however, some especial cases which appear to be exceptional, in consequence of the unnatural state in which we require plants to be preserved for our own peculiar purposes.

It has been remarked by one of the translators of this work that "care should be taken that plants in pots have not too great a quantity of moisture when they first begin to vegetate." Plants should not have too much moisture at any time. The meaning of the caution seems to be that, as plants in bud are less able to assimilate moisture than if in full leaf, so the supply of moisture to the former should be in proportion small. But this caution is needless if the cultivator recognises the general axiom that "PLANTS SHOULD NEVER HAVE MORE MOISTURE

THAN THEY CAN CONSUME," whether by assimilation, or rejection in the form of perspiration (see p. 65).

In the case of bulbs, which may be kept perfectly dry, while really at rest, when they are stimulated into growth, moisture must be administered with the greatest caution. When a bulb has lain dormant in the earth during its natural period, it is ready to spring into renewed life upon the application of warmth and moisture; and it may seem to matter little whether it is suddenly transferred from dryness to moisture, or whether the change takes place gradually; because its powers of life are unimpaired. But in nature no such sudden changes occur: on the contrary, when rain begins to fall, it soaks slowly into the earth; and when it reaches the bulb, it is still arrested in its action by the numerous dry coats with which this body is invested, and through which it must gradually filter. But when a bulb has been long out of the earth, its vital energies are much diminished, and it cannot bear even that slow supply of moisture which is furnished by wet soil, whose humidity penetrates the bulb coats, and is absorbed by the living tissue. If a weakened bulb is suddenly brought in contact with water, it will absorb it, but may be unable to digest it. The water will then become stagnant and putrid, and destroy the bulb; although, could the bulb have digested it, it would have been converted into new elements and have proved a proper aliment. The rule, therefore, to observe with newly-imported bulbs is, to place them where they absorb moisture very slowly. The driest earth is full of water, which can only be driven off by the application of intense heat. A bulb, therefore, should be planted in what is called dry soil, and placed in a shady part of a green-house until it has become plump, and begun to shoot; if it has begun to shoot when received, still the same treatment should be observed, and the driest soil used to plant it in. It is only when decisive signs of natural growth can be detected that a very little water should be given, while the temperature is at the same time slightly increased; and no considerable quantity of water should be administered until the leaves are an inch or two above ground, and evidently disposed to grow rapidly. If these precautions are taken, no failures are ever likely to occur; if neglected, no success can be anticipated. A chest full of bulbs of Calochortus macrocarpus, one of the rarest and finest of all plants, was destroyed in the Garden of the Horticultural Society by an unskilful gardener, who planted them in the wet earth of an open border immediately after their arrival from a fifteen months' voyage. Every bulb would have grown had he understood the principles of horticulture.

Dutch gardeners perfectly comprehend this, as will be seen from the following practical remarks on the management of Hyacinths, by Mr. Theodore Storm, one of the most experienced Dutch growers of this plant. Moisture being the most destructive agent against which the

amateur has to guard, great care should be taken to protect Hyacinths from it, by selecting the most elevated spot in his garden. If this is surrounded by a shallow trench, a little distance off, it will be useful; and the bed should also be raised seven or eight inches above the ground level. It must not be imagined that this precaution is useless because many parts of England are more elevated and lie drier than Holland, an opinion too prevalent among foreign amateurs, which occasions them the loss of many bulbs. In all the treatises that have appeared on the culture of the Hyacinth, this important circumstance has been almost wholly overlooked. The truth is, that the soil which suits the Hyacinth is very light, and disposed to absorb the rain and snow which falls between the months of November and March. The paths around the beds being more close and compact, do not absorb this moisture which lodges upon the beds, and renders them so wet that they absolutely become like mud to the depth of sixteen or twenty inches. The bulbs having by that time formed roots eight or twelve inches in length, their extremities are continually immersed in water, which, from want of a slope to carry it off, causes the roots to putrify, and to communicate a disease to the bulbs, which either totally destroys them, or renders the flowers poor and small. The bulb becomes weak, and when taken up will be found shrivelled and separating into scales. To prevent this there should always be a gentle descent or small trenches around the beds to drain off the wet. The surface of the beds should also be at least seven or eight inches above the path.

The vitality of a bulb being thoroughly aroused, and the leaves being in full and healthy action, many of these plants may almost be regarded as aquatics, their leaves being able to consume all the moisture that the roots, even though immersed in water, can absorb. Of this the Hyacinth is a familiar example; Crinums, Pancratiums, Hippeastrums, and all such soft-leaved genera are others, as is seen by the case of the Amaryllis Belladonna, which acquires its greatest beauty by the side of ditches in Madeira, where it is dried up at the period of rest, and deluged while in leaf.

One of the effects of an excessive supply of moisture is, to keep all the newly formed parts of a plant tender and succulent, and therefore such a constant supply is desirable when the leaves of plants are eaten as in the case of Spinach, Lettuces, and other oleraceous annuals. Another effect is, to render all parts naturally disposed to be succulent much more so than they otherwise would be; thus we find market-gardeners deluging their Strawberry plants with water while the fruit is swelling, in order to assist in that, to them, important operation. While, however, in this case, the size of the fruit is increased

by a copious supply of water to the earth, its flavour is, in proportion, diminished; for, in consequence of the rapidity with which the Strawberry ripens, and, perhaps, the obstruction of light by its leaves, the excess of aqueous matter taken into the system cannot be all decomposed, and formed into those products which give flavour to fruit; but it must necessarily remain in part in an unaltered condition.

It is for the reason just given that the quantity of water in the soil should be diminished when succulent fruit is ripening; we see this happen in nature, all over the world, and there can be no doubt of its being of great importance. Not only is the quality of such fruit impaired by a wet soil, as has just been shown, but, because of its low, perspiratory power, the fruit will burst from excess of moisture, as occurs to the Plum and Grape in wet seasons.

Some fruits are much more subject to this bursting or cracking than others, as is seen in the Stanwick Nectarine, the Chasselas musqué grape, &c. In such cases it is clear that the dryness of the soil is of more than ordinary importance.

It is also to be observed that bursting may arise from mere skin disease; as happens with mildewed or rusty grapes, in which, by one cause or other, the power of the skin to distend as the berries fill with fluid is destroyed—in the one case by the action of a mildew-plant, in the other by greasy fingers or currents of cold air, or impurities of the atmosphere caused by bad fumigation, sulphuring, &c.

The Melon, although an apparent exception to this rule, is not really so; that fruit acquires its highest excellence in countries where its roots are always immersed in water, as in the floating islands of Cashmere, the irrigated fields of Persia, and the springy river-beds of India. But it is to be remembered that the leaves of this plant have an enormous perspiratory power, arising partly from their large surface, and partly from the thinness and consequent permeability of their tissue, so that they require a greater supply of fluid than most others; and, in the next place, the heat and bright light of such countries are capable of decomposing and altering the fluids of the fruit with a degree of rapidity and force to which we here have no parallel. In this country the Melon does not succeed

if its roots are immersed in water, as I ascertained some years ago, in the Garden of the Horticultural Society, by repeated experiments. Melons were planted in earth placed on a tank of water, into which their roots quickly made their way; they grew in a curvilinear iron hot-house, were trained close under the glass, and were consequently exposed to all the light and heat that could be obtained. They grew vigorously and produced their fruit, but it was not of such good quality as it would have been had the supply of water to the roots been less copious. In the tropics, if the quantity of rain that falls in a short time is enormous, and plants are forced by it into a rapid and powerful vegetation, they are at the same time acted upon by free currents of warm air and a light and temperature bright and high in proportion, the result of which is the most perfect organization of which the plants are susceptible; but, if the same quantity of water is given to the same plants at similar periods in this country, a disorganization of their tissue is the result, in consequence of the absence of air, light, and heat in sufficient quantity.

The effect of continuing to make plants grow in a soil more wet than suits them is well known to be not only a production of leaves and ill-formed shoots, instead of flowers and fruit, but, if the water is in great excess, of a general yellowness of appearance, owing, as some chemists think, to the destruction, by the water, of a blue matter, which, by its mixture with yellow, forms the ordinary verdure of vegetation. If this condition is prolonged, the vegetable tissue enters into a state of decomposition, and death ensues. In some cases the joints of the stem separate, in others the plant rots off at the ground, and all such results are increased in proportion to the weakness of light, and the lowness of temperature. De Candolle considers that the collection of stagnant water about the neck of plants prevents the free access of the oxygen of the air to the roots; but the great mischief is undoubtedly produced by the coldness of the soil in which water is allowed to accumulate. It is also possible that the extrication of carburetted hydrogen gas is one cause of the injury sustained by plants whose roots are surrounded by stagnant water; but upon

this point we want much more satisfactory evidence than we yet possess.

Dr. Madden's views of the effects of drainage may be quoted in connection with this subject (see his prize essay). 1. One great evil produced by an excess of water in soil, is the consequent diminution in the quantity of air within it; which air we have proved to be of the greatest consequence, not only in promoting the chemical changes requisite for the preparation of the food of plants, but likewise to the roots of the plants themselves; for Saussure and Sir H. Davy have proved that oxygen and carbonic acid are absorbed by the roots; which gases, however, especially the former, can be conveyed to them only by the air. 2. An excess of water injures soil by diminishing its temperature in summer and increasing it in winter—a transposition of nature most hurtful to perennials, because the vigour of a plant in spring depends greatly upon the lowness of temperature to which it has been subjected during winter (within certain limits of course), as the difference of temperature between winter and spring is the exciting cause of the ascent of the sap. 3. The presence of a large quantity of water in soil alters the result of putrefaction, by which some substances are formed which are, in all probability, useless to plants,—such, for example, as carburetted hydrogen,—and diminishes the proportion of more useful ingredients, as ulmic acid. 4. An increase in the proportion of fluid in soil has a most powerful effect upon its saline constituents, by which many changes are produced diametrically opposite to those that take place in soil where the water is in much less quantity; and in this manner the good effects of many valuable constituents are greatly diminished, as, for instance, the action of carbonate of ammonia upon humus, and of gypsum upon carbonate of ammonia. 5. The directions of the currents which occur in wet soil are entirely altered by drainage; for whereas in undrained soil the currents are altogether from below upwards, being produced by the force of evaporation at the surface, and consequently the spongioles of the plants are supplied with exhausted subsoil water, when land is drained the currents are from the surface to the drains, and the roots are consequently in this manner supplied with fresh aërated water. Lastly, an excess of water in soil produces a constant dampness of the atmosphere, which we have shown to be injurious to plants in three distinct ways:—1. by diminishing evaporation, and thus rendering the process of assimilation slower; 2. By diminishing the absorption of the carbonic acid, and thus lessening the atmospheric supply of food; 3. By creating a tendency in the plant to produce leaves possessing a different structure from those which the same plant produces in dry situations. Thus we have six distinct methods in which an excess of water in soil has been proved to be greatly injurious to plants.

The removal of superfluous water by drainage has been already shown to be attended by an elevation of earth-temperature (see p. 137). Its other effects, of taking out of land the water which plants cannot assimilate (and no more), and at the same time of enabling rain water charged with salts of ammonia, a direct food of plants, to reach the roots with every shower, probably constitute the whole *rationale* of this important operation.

In bibulous soils lying high this contrivance may be unnecessary; but in those which are tenacious, or which, from their low situation, do not permit superfluous water to filter away freely, such a precaution is indispensable. No person has ever seen good crops produced by trees growing in lands imperfectly drained; and all experienced gardeners must be acquainted with cases where wet unproductive borders have been rendered fruitful by contrivances which are chiefly valuable because of their efficiency in regulating the humidity of the soil.

Such precautions as are detailed in the following good account of preparing a Vine border, show how important it is to provide effectually for the removal of superfluous water from roots, and how useless a waste of money is that which is expended in forming deep rich beds of earth. "In preparing a Vine border," says Mr. Griffin of Woodhall, a successful grower of Grapes, "one foot in depth of the mould from the surface is cleared out from the whole space; a main drain is then sunk parallel to the house, at the extremity of the border, one foot lower than the bottom of the border; into this smaller drains are carried diagonally from the house across the border. The drains are filled with stone. The cross drains keep the whole bottom quite dry; but if the subsoil be gravel, chalk, or stone, they will not be necessary. The drainage being complete, the whole bottom is covered with brick, stone, or lime rubbish, about six inches thick, and on this is laid the compost for the Vines." (*Hort. Trans.*, iv. 100.) This is in accordance with a practice well known in vineyard countries. "In France, in the Vine districts, where water frequently collects in great quantities at a certain depth in the earth, the trees are planted upon an under-layer of stones, which are covered with earth, and in this manner the roots are kept from too much moisture, and the water is drained away." (*German Translator.*)

The practice of placing large quantities of potsherds or broken tiles at the bottom of tubs, or pots, or other vessels in which plants are rooted, is only another exemplification of the

great necessity of attending to the due humidity of the soil, and to the prevention of stagnant water collecting about the roots. In like manner the injury committed by worms upon the roots of plants in pots chiefly consists in these creatures reducing the earth to a plastic state, and dragging it among the pot-sherds so as to stop up the passages between them and destroy the drainage.

One of the means of guarding the earth against an access on the one hand, and a loss on the other, of too much water, is by paving the surface of ground with tiles or stones, and the advantages of this method have been much insisted upon. But, in cold summers at least, such a pavement may prevent the soil from acquiring the necessary amount of heat; and it may in some degree obstruct the free communication between the atmosphere and the roots. It is therefore a practice that should be adopted cautiously.

It is in places fully exposed to the sun, and liable to "burn" in summer, in consequence of loss of moisture, that paving answers best. On heavy land where trenches have been formed to hold peat for American and similar fibrous-rooted plants, it is sometimes found impossible to keep them alive in summer until the surface is paved, after which they succeed perfectly. Here, however, it is found that the best kind of paving consists of round pebbles of gravel spread over the surface, with peat sifted between them. Flagstones, tiles, or large nodules of flint are objectionable.

More commonly recourse is had to the operation of simple watering, for the purpose of maintaining the earth at a due state of humidity, and to render plants more vigorous than they otherwise would be; an indispensable operation in hot-houses, but of less moment in the open air. It is, indeed, doubtful whether, in the latter case, it is not often more productive of disadvantage than of real service to plants. When plants are watered naturally, the whole air is saturated with humidity at the same time as the soil is penetrated by the rain; and in this case the aqueous particles mingled with the earth are very gradually introduced into the circulating system, for the moisture of the air prevents a rapid perspiration. Not so when plants in the open air are artificially watered. This

operation is usually performed in hot dry weather, and must necessarily be limited in its effects; it can have little if any influence upon the atmosphere: then, the parched air robs the leaves rapidly of their moisture, so long as the latter is abundant; the roots are suddenly and violently excited, and after a short time the exciting cause is withdrawn, by the momentary supply of water being cut off by evaporation, and by filtration through the bibulous substances of which soil usually consists. Then, again, the rapid evaporation from the soil in dry weather has the effect of lowering the temperature of the earth, and this has been before shown to be injurious; such a lowering, from such a cause, does not take place when plants are refreshed by showers, because at that time the dampness of the air prevents evaporation from the soil, just as it prevents perspiration from the leaves. Moreover, in stiff soils, the dashing of water upon the surface has after a little while the effect of "puddling" the ground and rendering it impervious, so that the descent of water to the roots is impeded, whether it is communicated artificially or by the fall of rain. It is, therefore, doubtful whether artificial watering of plants in the open air is advantageous, unless in particular cases; and most assuredly, if it is done at all, it ought to be much more copious than is usual. It is chiefly in the case of annual crops that watering artificially is really important; and with them, if any means of occasionally deluging ground can be devised by means of sluices or otherwise, in the same way as water-meadows, it may be expected to be the most advantageous.

The best gardeners employ overhead watering in the open air only in cases of absolute necessity. A curious case is recorded of a garden in a sandy soil at Tonbridge, in Surrey, which, through the hot and dry summer of 1842, remained in the most luxuriant beauty without receiving any assistance from watering. In this case the gardener stated that the garden in question was some eight years previously partly pond, and partly a sandy bank. The former was filled up with earth; the latter was removed to the depth of three feet. A compost prepared of sandy loam, decayed vegetable mould, silver sand, and lime, well mixed and seasoned, was substituted, to the depth of three feet; and, under these circumstances, although not even a thunder

shower fell, some Lobelias and Fuchsias were the only plants that needed water.

Watering is, however, sometimes indispensable. When that is so, various plans are adopted to increase its efficiency, and as a substitute for overhead showers. Mr. S. Taylor, in the *Gardener's Magazine* for 1840, recommends the use of bottles, with two small holes in the sides, near the bottom. The bottles are buried to the neck near the roots of the flower which requires watering; and after being filled and corked, the water is allowed gradually to exude through the holes. This is objectionable, because the roots of the plants are liable to be injured in plunging the bottles, and it requires too many of them, where copious watering is necessary. Mr. W. P. Ayres thinks—"A better plan is to take moderate-sized flower-pots, and having placed an inch or two of rough gravel in the bottom of each, to place them round the plant to be watered, and fill them with water, which as it percolates gradually through the gravel, will soak into the ground. For plants such as Standard Roses, Rhododendrons, &c., closely turfed over on lawns, or for anything in a sloping situation, this is a most excellent plan, as the pots filled with water may be placed at night and removed the next morning, so as not to become an eyesore. Watering plants in flower-beds is at all times a difficult matter, because if the borders are sufficiently full of soil to give them a convex form, which they always ought to have, the water runs to the sides of the borders as fast as it is poured on. In such cases it will be found advisable to perforate the beds as thickly as possible, without injuring the roots, to the depth of six or eight inches, with a stick one inch in diameter, and by filling these ten or a dozen times the ground will become thoroughly soaked. With Annuals, Verbenas, and other grouping plants, I have found this a most excellent method."

The TIME OF DAY at which watering should be practised in the open air has given rise to much difference of opinion. Some gardeners insist upon the morning, others upon the evening. The first rest their opinions upon such considerations as the following: "Two acknowledged agents in vigorous growth are heat and moisture; plants out of doors must take the heat as they find it, and as we cannot increase, our object should be not to diminish it: moisture is under our control, but if we exercise that control, and water our plants in the evening during dry weather, we do so at the expense of a great portion of the heat we desire to preserve. Two influences are at that time brought into operation in cooling down the plants, and retarding their growth, which we thus vainly endeavour to urge forward by moisture: these are evaporation and radiation. Evaporation is the more rapid in proportion to the dryness of the air; and hence it is most energetic, when the necessity for watering is most urgent: but evaporation cannot take place without producing cold, and that cold is proportionate to the

rapidity of the process. Chemistry points out the reason of this, vapour having a greater capacity for heat than water, the heat sensible in the water becomes latent in its vapour, and the sensible temperature falls; additional heat to keep up the temperature not being quickly enough supplied by the surrounding media. Let us look at the effect of this evening's supply of water to plants: the air is dry, evaporation goes on briskly; the temperature sinks, the plants are chilled, there are no sun's rays to communicate fresh warmth, and their growth is sometimes even more unsatisfactory than that of such plants as are growing in the apparently arid soil, and which have been allowed to take their chance. The other source of diminished temperature I noticed was radiation: every warm body tends continually to throw off its heat to all others of lower temperature, near or remote: but radiation in meteorology is more particularly confined to 'the radiation of heat from the surface of the earth and objects on it into a clear sky.' All objects do not radiate heat with equal rapidity: rough surfaces do it more readily than smooth, and dark surfaces than those of a lighter shade of colour. Apply the latter remark to the process of evening watering: almost all soils are darkened in their colour by moisture, and hence soil by this practice is reduced to the best possible condition for getting cooled down during the night."

This is, in fact, a commentary upon what the French call the *Lune Rousse* or April moon, which they fancy rusts their crops. M. Arago has shown that this notion is erroneous, the effect alluded to being clearly owing to another cause, but one which must necessarily be in active operation on bright moonlight nights. He observed that in the months of April and May the temperature at night is often not more than four or six degrees above the freezing point; and under these circumstances, when the sky is most unclouded and the moon shining brightest, heat will be radiated from the earth sufficient to reduce the temperature at the surface some degrees lower, or below freezing point; hence the tender leaves and roots of plants are nipped by cold, and that appearance given to the former which is intended to be conveyed by the French word *rousse*. But it may be doubted whether, under such conditions as are above assumed to exist, watering should be practised at all. The principle is not to water if it can be avoided; it is in hot dry weather that the operation is most needed, and at that time the lowering of temperature at night is more beneficial than disadvantageous. It is evident indeed that the arguments just quoted are altogether one-sided, the real questions to be determined are, 1st, Whether such a loss of heat is detrimental to plants? and 2ndly, Whether there may not be some compensating advantages? We believe that all plants are retained in a more healthy state by lowering their temperature at night, and that no error is greater than that of supposing warm nights advantageous to them. In all countries nature cools down the

soil very considerably at those seasons when plants are growing, and she ceases to do so only when vegetation is exhausted—or, perhaps, we ought rather to say, vegetation is exhausted when she ceases to do so. It is doubtless true that this cooling process may be carried too far. But that the amount of evaporation is not very considerable at night, is shown by the damp state of the soil the next morning after a watering. In watering at night the ground is soaked with moisture at a time when plants are exhausted of their fluids in consequence of the perspiration that has been going on all day long; the sooner that loss is supplied the better; and during the night, when perspiration ceases, or very greatly diminishes, a plant is enabled to absorb by its roots the water it wants, so that by the return of day it is filled with fluid, and in the best possible state to resist the renewed action of the sun. But when water is applied in the morning the result is very different. The plant is called on to throw off moisture by its skin before it has been refilled by the absorbing action of the roots; the ground, too, which at night retains its water and conveys it to a plant, is called on to give it up immediately to the dry, warm, and gradually heating air. So that, in fact, a morning's watering cannot convey to the interior of a plant anything like so much water as that of the evening.

I entertain no doubt that the great object of the cultivator should be to avoid the necessity of watering; by shading the earth, or the plants themselves, or by the common operations of mulching and top dressing.

When watering is inevitable the TEMPERATURE OF THE WATER is a matter of great moment. Theoretically water should always be a few degrees warmer than the soil; practically this cannot be always ensured. All that a gardener can do is to keep his attention fixed upon the principle. In summer the earth may be taken to stand at 60° while cold spring water is not more than 50°; to be beneficial the water ought to be 62° at least; if warmer so much the better. For this reason water from ponds or other places heated by the sun, should always be employed when circumstances permit it. In hot-houses rain water is now generally preserved in raised tanks which acquire the temperature of the house. By such means warm water is secured. The practice has been arrived at by the teaching of experience, which shows that cold water applied to the roots of hothouse or greenhouse plants, is in the highest degree injurious, if not fatal.

Among the evils of watering plants, is hardening the soil by the mechanical action of water frequently dashed upon it. In this way a hard crust is formed upon heavy soil, or the particles of sandy land are forced together into a compact mass, which interferes with the percolation of rain, and the free access of air to the roots. It is for this reason, that the application of liquid manure by engines, or by any contrivance that may cause it to fall from a height, is regarded as objectionable, and

even likely to frustrate the object for which it is used. To meet this difficulty subterranean irrigation, by means of pierced pipes filled with fluid under pressure, has been advocated by Mr. Chadwick, Mr. Kennedy and others; and there is no doubt that it is the most effectual and unobjectionable of all methods proposed for communicating fluids to the soil. It is, however, to be feared that cost will always be a bar to the adoption of this plan.

Mildew, which is so often produced by cold dry air acting upon a delicate surface of vegetable tissue, is completely prevented *in annuals* by very abundant watering. The ravages of the Botrytis effusa, which attacks Spinach; of Acrosporium monilioides, which is found on the Onion; and the mildew of the Pea, caused by the ravages of Erysiphe communis, may all be stopped or prevented by abundant watering in dry weather.

Mr. Knight first applied this fact to the securing a late crop of peas for the table, in the following manner:—The ground is dug in the usual way, and the spaces which will be occupied by the future rows are well soaked with water. The mould upon each side is then collected, so as to form ridges seven or eight inches above the previous level of the ground, and these are well watered; after which the seeds are sowed, in single rows, along the tops of the ridges. The plants very soon appear above the soil; and grow with much vigour, owing to the great depth of the soil, and abundant moisture. Water is given rather profusely once in every week or nine days, even if the weather proves showery; but, if the ground be thoroughly drenched with water by the autumnal rains, no further trouble is necessary. Under this mode of management, the plants will remain perfectly green and luxuriant till their blossoms and young seed-vessels are destroyed by frost, and their produce will retain its proper flavour, which is always taken away by mildew. (*Hort. Trans.*, ii. 87.)

CHAPTER III.

OF ATMOSPHERICAL MOISTURE AND TEMPERATURE.*

THE constituents of the atmosphere that surrounds us are either the same in different regions, or the differences, if any, are not appreciable by chemical processes. It is far otherwise, as regards temperature and humidity, which are so intimately connected that they cannot be considered apart from each other.

From what has been already stated (Book I. Chap. V.), it is apparent that of the vital functions of plants none are more important than perspiration and evaporation; and that, while a certain amount of loss of fluid particles is necessary to them, a great excess or diminution of the loss must be injurious. Although the solar rays appear to be the immediate cause of perspiration, which proceeds in proportion to their intensity, yet this action is necessarily modified by the state of the medium, that is, of the atmosphere, which surrounds them; in proportion to its heat and dryness will their power be augmented, and in proportion to its cold and moisture diminished. The physiological effect of an excessive augmentation of perspiration is to dry up the juices and to destroy the texture of the leaves; on the other hand, an excessive obstruction of that function prevents the decomposition and assimilation of fluids, and the formation of new organised matter, as well as of

* This subject has already been fully treated by the late Professor Daniell, in his excellent paper "On Climate with regard to Horticulture," published in the *Transactions of the Horticultural Society*, vol. vi. p. 1. It is impossible to discuss the same topic without profiting largely by this important treatise, which I have much followed in the present chapter.

the secretions peculiar to a species. A state of the atmosphere, therefore, which is most favourable to the maintenance of the perspiratory action in the most healthy state, is that which it must be the business of a gardener to secure by all the means in his power.

The fitness of an atmosphere for maintaining a healthy vegetation depends upon the amount of moisture suspended in it, and upon its temperature. The *hygrometer* indicates the former, as the *thermometer* does the latter.

Among the hygrometers intended for measuring the quantity of elastic vapour in the atmosphere, the most convenient for use is that invented by Daniell. In this instrument, the amount of moisture in a given atmosphere is indicated by what is called the *dew-point;* that is to say, by the point of the thermometric scale at which the cold is sufficient to cause a deposition of dew.

It is impossible for any one to know what degree of moisture he really maintains in a forcing-house without an instrument by which to measure it; that instrument is the hygrometer. Of Daniell's hygrometer the annexed cut exhibits the general appearance. It measures the moisture in the air quickly and precisely, and is not subject to get out of order. The air we breathe is a permanently elastic fluid, containing watery vapour in mixture, its power of retaining which is greater when temperature is high than when low. It may be compared to a sponge; if this substance, when dry, is soaked in water, a portion of the fluid is absorbed; but if the sponge is again dipped without squeezing, and before it has had time to dry, no additional quantity of water will be taken up by it, because the first immersion saturated it; in like manner, when air has taken up as much moisture as it can contain, it is said to be in a state of *saturation.* If when thus saturated a reduction of temperature takes place, the capacity of the air for moisture is diminished, and precipitation ensues. When air, on the contrary, is in an undersaturated, or dry state, it takes up moisture from the substances with which it comes in contact. If moist air is brought into contact with a substance sufficiently colder, a part of the moisture is *condensed,* and is so converted from a state of invisible vapour into water. If, for instance, a cold wine-glass is brought into a warm room, the sides of the glass become covered with dew, which is the water that existed in the air as vapour, and which, condensed on the cold glass, is changed into water. The effect, therefore, of bringing warm moist air into contact with a cold surface is to rob the air of a part of its moisture. Thus, in a cold night, the glass roof of a greenhouse may be seen streaming with water, which runs down and forms "drip," and in this often unsus-

pected manner air is rendered dry, notwithstanding the operations of syringing, steaming, &c. Daniell's hygrometer is constructed with reference to these considerations. The figure represents two hollow glass balls, containing ether, and communicating by the glass tube which rests on the support. The ball which forms the termination of the longer leg is of black glass, in order that the formation of dew on its surface may be the more perceptible; it includes the bulb of a delicate thermometer, dipping in the ether, its scale being inclosed in the tube above the ball; and whatever change takes place in the temperature of the ether is indicated by this thermometer. The other ball is covered with muslin. In making an observation, it is first necessary to note down the temperature of the air, next to turn the instrument so that when the muslin-covered ball is held in the hand the ether may escape into the blackened ball; and it should also be held till the included thermometer rises a few degrees above the temperature of the air, when it should be replaced on the support. Then drop, or gently pour, a little ether on the muslin; the evaporation of this extremely volatile substance produces cold, and attention must be instantly directed to the black glass ball and included thermometer; the latter will be seen falling rapidly, and at length a ring of dew will appear at the line which runs across the black ball,—quickly if the air is very moist, slowly if the air is dry. If the air is in a very dry state no moisture will be thus deposited till the thermometer falls to perhaps 10°, 20°, or 30° below the temperature of the air; but at whatever temperature the dew forms that temperature should be noted as the *dew-point* and the difference between it and the temperature of the air at the time is the *degree of dryness* according to the indications of this hygrometer; thus, in a moderately dry day, let it be supposed that the temperature of the air is 65° in the shade, and that the muslin requires to be kept moist, before dew is formed, till the blackened ball containing the ether has its temperature reduced to 50°, as indicated by the included thermometer, there are then said to be 15° of dryness. Again, supposing the temperature is 85°, and the dew-point found, as before, to be 70°, the degree of dryness is still expressed by 15°; but the quantity of moisture diffused in the air is, notwithstanding, somewhat greater in the latter case than in the former. If 1000 represent complete saturation, the quantity of moisture when the temperature is 65° and the dew-point 50°, will be 609; but when the temperature is 85°, and the dew-point 70°, the moisture will be represented by 623; these numbers being ascertained by tables prepared for the purpose. The difference, however, in such a case, is so small that it is not worth taking into account in a horticultural point of view. But as these numbers can only be ascertained by calculation it is more convenient to reckon by the degrees of dryness, bearing in mind that the dryness of the air is indicated by the difference between the temperature of the

air and of the dew-point. Thus, if the ring of dew is formed as soon as ether is applied, and only one degree of difference is observable, the air is nearly saturated; if the difference is 5° to 10°, the dryness is very moderate, while 15° to 20° of difference indicate excessive dryness, and beyond this the air is parching.

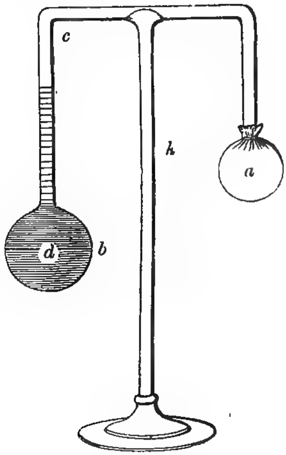


Fig. XXIX.

The objection to this instrument consists in its not being well suited to the hands of a person unaccustomed to use philosophical apparatus. In order to overcome this difficulty, Mr. Harris has proposed the following contrivance. "It consists of an old-fashioned instrument commonly sold in the opticians' shops as Leslie's differential thermometer, (Fig. XXX. in the opposite page). It is arranged so that when not in use the fluid stands at zero in the stem, A; over the bulb of the *opposite* stem, I, place a piece of muslin, C, which has been well soaked in a strong solution of common salt in water; the muslin having been cut into a circular shape, is laid on the bulb whilst wet, and the moisture will make it adhere sufficiently. A shelf, or bracket, with sides, top, and back, is made for it to stand on, to seclude it from the sunshine, an essential precaution, and also to prevent the damp wall from having effect upon the muslin, so that it may draw all its moisture from the atmosphere alone. It will be found convenient to have a thermometer hung on the same stand, as in all hygrometric observations the state of the thermometer must be attended to. The rationale of its action is simple. If the absorption of moisture exceeds the evaporation from the muslin, heat will be generated which will expand the air in the bulb, C, and drive the fluid up the opposite stem, indicating the degree by

its rise. On the contrary, if the evaporation exceeds the absorption, cold will be produced, causing the fluid to fall. The general range of the scales made are from zero to 40°. In Mr. Harris's stove, under the general treatment of orchidaceous plants, temperature ranging from 78° to 95°, the hygrometer usually ranged from 15° to 30°."

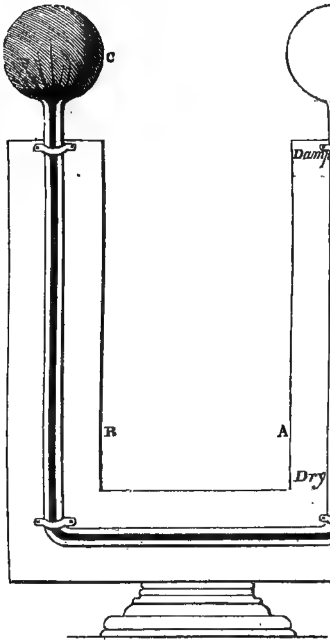


Fig. XXX.

Of this instrument it has been complained that its divisions are in a great measure arbitrary and different from those of the thermometer to which gardeners are accustomed. But this is unimportant, inasmuch as men soon become acquainted with the value of the indications of any instrument, and it gives an absolute, if not a comparative result, which latter may be dispensed with. Mr. Wailes has expressed his opinion that "the wet-bulb thermometer, which has been long known, though recently improved in form, under the name of Mason's Hygrometer, is the one best fitted for the hothouse, being 'simple, self-acting, economical, and certain,' and requiring the least attention to keep it in working order. Mason's instrument is, however, not indispensable, as every gardener may readily convert any common thermometer into

a hygrometer. All that is required is to cut away a portion of the wood on which the tube is mounted, so as freely to expose the bulb, and to cover the latter with a fold of cambric, to which water must be supplied by means of a few threads from a phial placed near. Of course another thermometer, to indicate the temperature of the air, requires to be suspended near to that with the wet bulb, and care must be taken that, when dry, both mark the same degree of heat. To be quite accurate the dry-bulb thermometer should be covered with a similar piece of cambric, though this is hardly necessary, and may be inconvenient where the syringe is so often used.

The mode of using any wet bulb thermometer is explained by the following table and the remarks accompanying it, which were published some years ago by Mr. Wailes, of Newcastle.

TABLE OF THE DEW-POINT WHEN THE TEMPERATURE OF THE AIR, IN THE SHADE, IS BETWEEN 55° AND 100° OF FAHRENHEIT.

Temperature.	Difference between the dry and Moistened Thermometers in degrees of Fahrenheit.														
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
55°	53	50	48	46	43	41	39	36	34	32	29	27	25	22	20
56	54	51	49	47	44	42	40	37	35	33	30	28	26	23	21
57	55	52	50	48	45	43	41	38	36	34	31	29	27	24	22
58	56	53	51	49	46	44	42	39	37	35	32	30	28	25	23
59	57	54	52	50	47	45	43	40	38	36	33	31	29	26	24
60	58	55	53	51	48	46	44	41	39	37	34	32	30	27	25
61	59	56	54	52	49	47	45	42	40	38	35	33	31	28	26
62	60	57	55	53	50	48	46	43	41	39	36	34	32	29	27
63	61	58	56	54	51	49	47	44	42	40	37	35	33	30	28
64	62	59	57	55	52	50	48	45	43	41	38	36	34	31	29
65	63	60	58	56	53	51	49	46	44	42	39	37	35	32	30
66	64	61	59	57	54	52	50	47	45	43	40	38	36	33	31
67	65	62	60	58	55	53	51	48	46	44	41	39	37	34	32
68	66	63	61	59	56	54	52	49	47	45	42	40	38	35	33
69	67	64	62	60	57	55	53	50	48	46	43	41	39	36	34
70	68	65	63	61	58	56	54	51	49	47	44	42	40	37	35
71	69	66	64	62	59	57	55	52	50	48	45	43	41	38	36
72	70	67	65	63	60	58	56	53	51	49	46	44	42	39	37
73	71	68	66	64	61	59	57	54	52	50	47	45	43	40	38
74	72	69	67	65	62	60	58	55	53	51	48	46	44	41	39
75	73	70	68	66	63	61	59	56	54	52	49	47	45	42	40
76	74	71	69	67	64	62	60	57	55	53	50	48	46	43	41

TABLE OF THE DEW-POINT, &c., *continued.*

Temperature.	Difference between the Dry and Moistened Thermometers in degrees of Fahrenheit. (*Continued.*)														
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
77°	75	72	70	68	65	63	61	58	56	54	51	49	47	44	42
78	76	73	71	69	66	64	62	59	57	55	52	50	48	45	43
79	77	74	72	70	67	65	63	60	58	56	53	51	49	46	44
80	78	75	73	71	68	66	64	61	59	57	54	52	50	47	45
81	79	76	74	72	69	67	65	62	60	58	55	53	51	48	46
82	80	77	75	73	70	68	66	63	61	59	56	54	52	49	47
83	81	78	76	74	71	69	67	64	62	60	57	55	53	50	48
84	82	79	77	75	72	70	68	65	63	61	58	56	54	51	49
85	83	80	78	76	73	71	69	66	64	62	59	57	55	52	50
86	84	81	79	77	74	72	70	67	65	63	60	58	56	53	51
87	85	82	80	78	75	73	71	68	66	64	61	59	57	54	52
88	86	83	81	79	76	74	72	69	67	65	62	60	58	55	53
89	87	84	82	80	77	75	73	70	68	66	63	61	59	56	54
90	88	85	83	81	78	76	74	71	69	67	64	62	60	57	55
91	89	86	84	82	79	77	75	72	70	68	65	63	61	58	56
92	90	87	85	83	80	78	76	73	71	69	66	64	62	59	57
93	91	88	86	84	81	79	77	74	72	70	67	65	63	60	58
94	92	89	87	85	82	80	78	75	73	71	68	66	64	61	59
95	93	90	88	86	83	81	79	76	74	72	69	67	65	62	60
96	94	91	89	87	84	82	80	77	75	73	70	68	66	63	61
97	95	92	90	88	85	83	81	78	76	74	71	69	67	64	62
98	96	93	91	89	86	84	82	79	77	75	72	70	68	65	63
99	97	94	92	90	87	85	83	80	78	76	73	71	69	66	64
100	98	95	93	91	88	86	84	81	79	77	74	72	70	67	65

The bulbs of both thermometers should be covered with a fold of white silk or muslin, and pure water supplied to one of them from a phial or other vessel placed near it, by a thread of floss silk acting as a siphon. The cover of the moistened bulb and the thread must be renewed occasionally.—The above table is sufficiently accurate for all practical purposes, but the true decreasing ratio is 2·33 for each degree of depression indicated by the moistened thermometer.*

After having obtained by Mason's hygrometer, 1st, the temperature of the air, as indicated by the dry thermometer, and, 2nd, the difference

* To find the corresponding degree of Leslie's hygrometer, multiply the number of degrees of difference between the dry and moistened thermometers by 6.

between that and the indication of the wet-bulb thermometer, the dew-point can be ascertained by the accompanying table thus:—

Supposing the temperature of the air, as indicated by the dry thermometer, is	70°
Whilst the wet-bulb thermometer is	64°
Degrees of dryness by this instrument	6°

If we look in the left hand column, headed "temperature," we shall find 70°; opposite this, and under 6° in the top column, we find 56°, the dew-point, or temperature at which the dew is deposited, according to Daniell's hygrometer, and 70°—56°=14° the degree of dryness by Daniell's instrument. By practice, or rather experience, a gardener would form as true a notion of the condition of his plants, with regard to moisture, by the indications of one instrument as he would by the other. He would learn that by Mason's 3° was a moderate state of dryness, but that 12° was excessive, just as easily as he would by observing 7° of dryness was moderate, according to Daniell's, but that 28° was parching (3 and 7, 12 and 28 are the corresponding degrees on the two instruments). So far these instruments are on an equality as regards their results; whilst Mason's has the advantage of not requiring any experiment to be made, nor an expensive substance like ether to be applied.

Other modifications may be adopted, such as Rutherford's thermometer; or by using Six's, or one constructed after Dr. Traill's method, the maximum and minimum of moisture can be registered by one bulb. Finally there is Simmons's Hygrometer, or more properly hygroscope, which has been much used, and of which a full account by Mr. Belville will be found in the *Gardener's Chronicle* for 1847, p. 815. The fault of this is that like all wood hygroscopes it is apt to get out of order, and to lose its hygrometrical property with time.

By means of these and similar contrivances, we are at all times able to ascertain exactly the quantity of water that exists in an elastic state in the air. When the hygrometer was first brought into use, what was called a damp atmosphere was frequently seen to indicate a degree of moisture falling short of ·500, saturation being represented by 1000; and it was found that ·120 was not uncommon—a state of things sufficient to impair the vitality of the most vigorous vegetation.

In this country, the changes of moisture are said to extend from 1·000, or saturation, to ·389, or even so low as ·120, under a south wall for a short space of time; "a state of dryness

which is certainly not surpassed by an African harmattan," but one which produces less disastrous consequences, because it is accompanied by a far lower temperature and a weaker solar radiation. The mean degree of moisture of the air near London has been found by Mr. Thompson to be ·897, on an average of ten years, while the mean temperature is 50·62 :* in other parts of the world it is very different; and the amount of those differences, together with the means of imitating them artificially, constitutes one of the most delicate and difficult parts of the gardener's art. All that relates to this subject, however, to be treated usefully, must be considered in a very special way, and in such detail as can only be expected in a separate work upon the subject. An idea of the difference between the atmospherical moisture of London and that of other parts of the world may, however, be collected from the following table showing the amount of rain that falls in a few different countries.

	Inches per annum.	
LONDON	24·01	Average of 10 years.
St. Petersburg	16·	
Algiers	27·	
Fattehpúr (East Indies)	35·94	Average of 4 years.
Madeira	31·	
Ságar (East Indies)	31·15 to 64·76	
Sikkim, at 11,000 feet	40·	
Bahamas	54·99	
Calcutta	59·83 to 81·	
Ceylon	84·3	
Macao	48·8 to 107·3	
Equator	96·	
Dorjiling	122·26	
Coast of Malabar	123·50	Average of 14 years.
Grenada	126·	
Leogane, St. Domingo	150·	

Bengal	20 to 22 inches in a single month.
Bombay	32 inches in 12 days.
Tavoy	203·5 inches in six months; as much as 8·5 in a day (July 31, 1831).

* See the various meteorological journals published by the Horticultural Society, in their *Transactions*, from the year 1826 inclusive.

We possess, to a small extent, the power of modifying the moisture of the air, even in the open air, and have almost complete control over that of glazed houses.

It is found by experience that the effect of wind is to increase the dryness of the air, and, consequently, the perspiration of vegetable surfaces. It is through wind that the moisture of plants and the earth is constantly borne away, and thus the evaporation of plants is increased. "Evaporation," says Daniell, "increases in a prodigiously rapid ratio with the velocity of the wind; and anything which retards the motion of the latter is very efficacious in diminishing the amount of the former. The same surface which, in a calm state of the air, would exhale 100 parts of moisture, would yield 125 in a moderate breeze, and 150 in a high wind." Hence, the great importance, in gardens, of walls and screens, which break the wind, and keep the air in repose in their vicinity. The difference between the effect of a given amount of cold upon the blossoms of exposed fruit trees, and those of the same species trained upon walls, is well known; and appears to be owing to this circumstance, much more than to any difference of temperature in the two situations.

This has been illustrated by Howard, in the results of some interesting experiments made by him on the annual amount of evaporation. During three years, in which the evaporating gauge was placed forty-three feet from the ground, the annual average result was 37·85 inches; during other three years, when the instrument was lower and less exposed, the average was 33·37 inches; and when the gauge was upon or near the ground, the annual average was only 20·28 inches, or little more than half the amount evaporated in a free and elevated exposure.

It is to be remarked that the easterly winds are, in this country, both the coldest and the driest. Daniell tells us that the "moisture of the air flowing from any point between N.E. and S.E. inclusive, is, to that of the air from the other quarters of the compass, in the proportion of ·814 to ·907, upon an average of the whole year;" and Mr. Thompson has found the hygrometer to indicate not uncommonly from 20° to 30° of dryness, during the long prevalence of the north-easterly winds in spring. At the same time, the air is very cold, the effect of which is to cause the sap-vessels of the stem to contract, and

refuse to convey their fluid, so that the blossoms of fruit-trees in a north-east wind, while they are robbed of their fluid contents by evaporation, can get no assistance from the roots through the stem, and necessarily perish; and this is no doubt one reason why open standard trees cast their flowers under a low temperature during the cold dry winds of our springs.

I have now before me a standard Washington Plum, bearing a crop of fruit in a garden where nearly everything else lost its blossoms on the 24th of April, 1854, when the thermometer fell to 18° Fahr. In this case a pile of firewood had been heaped round the stem to the height of the branches, and thus effectually guarded it from cold. Probably something was also owing to the warmth radiated from the pile of wood. This, however, only belongs to a class of facts of which the Magnolia grandiflora is an instance. Formerly there were trees of this species in Paris, whose only protection in winter was a heap of dry straw piled over their roots, so as entirely to cover them, and thatched to the height of five or six feet, so that the head of the trees formed the apex of a cone, the base of which was straw. By this precaution the earth is unable to freeze, and the fluids in the interior of the tree are maintained at a temperature approaching to that of the earth. While, on the other hand, if the earth is frozen hard, the fluids in the roots are frozen also, and they thus tend to lower the temperature of the fluids and the branches. But this is, perhaps, not the only reason why tender trees are preserved by this sort of protection. It is to be observed that the destructive effects of frost are in proportion to the succulence of the parts on which it acts; and it may be, that the contracting influence of cold gradually forces the fluids out of the unprotected branches into those lower parts which are guarded from the action of cold. Then the branches being *pro tanto* emptied of fluid, or dried, are thus deprived of a part of their susceptibility to cold.

It has been objected by a critic that there is no experimental proof of contraction of tissue taking place under the influence of cold. But if the reader will turn to Biot's curious and little known observations, briefly reported in *Henslow's Botany*, p. 205, he will find that contraction under cold has received the most conclusive experimental proof at the hands of one of the best of modern observers. There is also a fact on record which has hitherto remained without explanation, but which was probably connected with the contracting power of cold. In the winter of 1838, when the thermometer fell to 2° Fahr., Mr. Rogers observed the following phenomena:—During the extreme cold the branches of a Lime-tree, which overhung a part of his garden, drooped so as completely to lie upon the ground, and those above fell proportionately. The branches

recovered themselves as the day advanced and *grew warmer*, and eventually they so completely regained their original position that Mr. Rogers at first thought his gardener had cut away all that drooped and impeded the path the day before. In this case it is almost certain that the drooping was caused by the expulsion of air and fluid from the tissue by the contraction caused by cold, and that the revival was attributable to the reflux of air and fluid.

I find, however, from Mr. Thompson's observations, that the greatest dryness we experience in this climate is, not when the wind is in the east, but when it is in the south. For example: in nine years, between 1826 and 1834, the four driest days were in the year 1834, in June, when it was 33° on the 1st, 35° on the 2nd, and 31° on the 21st; on the 1st of June, 1833, it was 30°, and always with a south wind; and, during the whole of those nine years, there was but one other day on which the dryness was found as high as 30°, namely, on the 10th of April, 1834, with a north-east wind. The duration of dryness, with a south wind, was, however, very short, not exceeding one or at most two days, and was invariably accompanied with great heat and followed by heavy rain, while the north-easters last for weeks, without rain, and with a comparatively low temperature. The following statement puts this in a clear light. There occurred between 1826 and 1834, inclusive,—

Wind North		7	days, above 20° of dryness.
,, North-East	114	39	,, ,, ,,
,, East		48	,, ,, ,,
,, South-East		27	,, ,, ,,
,, South		35	,, ,, ,,
,, South-West		30	,, ,, ,,
,, West		35	,, ,, ,,
,, North-West		22	,, ,, ,,

These facts sufficiently explain the fatal effects of certain winds upon vegetation, the small comparative value in this country of walls with north and east aspects, and the general want of success that attends late spring planting. Here, also, we in part discover an explanation of the utility of shades interposed between the sun and plants newly committed to the earth: they not only cut off the solar rays, but also intercept

currents of air, and thus diminish the amount of perspiration by two opposite methods.

For screening plants from dry winds various means are employed, of which the following is a good example. In France a basket is employed, composed of two moveable semi-cylinders, constructed in the way of straw hives. To these semi-cylinders are fixed solid feet of wood, for the purpose of being driven into the ground. If it is only necessary to shelter one plant from east or north-east winds, one semi-cylinder is sufficient; but if it is a plant which you are forced to protect, is delicate, and requires a more complete protection, you inclose it between the two semi-cylinders fixed one to the other by means of hooks represented in the drawing. A lid of the same construction, furnished at its edge with a circle in woodwork, is fitted, when necessary, upon the cylinder, and thus, perhaps, offers a more effectual shelter against the severity of cold winds and excessive heat than any other. These sorts of shades are light to move, very solid, and very warm; for, letting but little of the exterior air penetrate, they preserve at night the heat which accumulates in the interior. They also guard plants well from the action of sun, and thus offer a means of checking the natural perspiration of green parts.

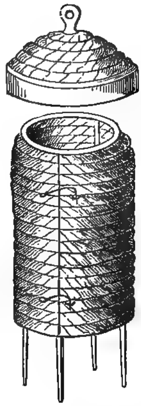


Fig. XXXI.

The following table, for which I am again indebted to Mr. Thompson, will be found to show that the average degree of dryness, in the middle of the day, throughout the year, is, with a—

	Degrees of Dryness.		Amount of Moisture.
North wind	6·55	=	816
North-east	7·30	=	794
East	6·20	=	825
Average, with wind from the three coldest points	6·68	=	811
South wind	4·23	=	877
South-west	4·70	=	859
West	6·20	=	733
Average, with wind from the three warmest points	5·04	=	823

A TABLE SHOWING THE TEMPERATURE, DRYNESS, AND MOISTURE OF THE AIR, WITH RELATION TO THE WIND, FOR THE YEAR 1831; calculated by Mr. Robert Thompson, from the Meteorological Observations made in the Garden of the Horticultural Society of London.

1831.	NORTH.					NORTH-EAST.					EAST.					SOUTH-EAST.				
	THERMOMETER.			HYGROM.		THERMOMETER.			HYGROM.		THERMOMETER.			HYGROM.		THERMOMETER.			HYGROM.	
	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.
January	34·2	29·0	31·6	3·7	882	37·0	27·1	32·0	3·3	893	43·6	34·5	39·0	0·3	989	44·3	38·3	41·3	0·0	1000
February	43·0	35·0	39·0	6·0	815	44·0	31·0	37·5	12·0	657	43·6	31·3	37·4	0·3	992	..	..	..	..	..
March	..	..	..	..	..	47·0	40·0	43·5	10·6	688	49·6	37·5	43·5	8·0	752	..	..	..	..	..
April	63·5	43·0	53·2	9·5	747	58·8	38·3	48·5	7·5	778	61·7	45·5	53·6	4·2	870	61·6	45·0	53·3	7·6	775
May	73·4	47·0	60·0	10·3	718	67·2	44·0	55·0	11·6	687	64·0	42·5	53·0	15·7	574	61·5	42·0	51·7	8·0	767
June	66·0	49·0	57·5	10·0	721	74·0	41·0	57·5	17·0	572	..	..	..	..	..	..	..	..	..	..
July	..	..	..	..	..	73·0	49·0	61·0	11·0	703	78·5	51·0	64·7	13·2	662	..	..	..	..	..
August	75·8	53·8	64·8	2·0	773	73·5	57·0	65·2	5·5	836	77·5	56·7	67·1	10·7	690	..	..	..	..	..
September	65·2	48·2	56·6	3·0	907	65·0	49·0	57·0	0·0	1000	67·0	48·3	57·6	10·0	723	..	..	..	..	..
October	..	..	..	..	..	..	..	..	..	..	58·0	45·0	51·5	0·0	1000	61·0	45·0	53·0	3·0	904
November	..	..	..	..	..	36·0	27·0	31·5	0·0	1000	46·0	29·0	37·5	0·0	1000	46·0	27·0	36·5	0·0	1000
December	44·0	34·0	39·0	1·0	971	40·0	26·5	33·2	2·5	920	..	..	..	..	..	43 0	29·0	36·0	0·0	1000
Means	58·1	42·3	50·2	6·5	816	55·9	39·0	47·4	7·3	749	58·9	42·1	50·5	6·2	825	52·9	37·7	45·3	3·2	907

1831.	SOUTH.					SOUTH-WEST.					WEST.					NORTH-WEST.				
	Thermometer.			Hygrom.		Thermometer.			Hygrom.		Thermometer.			Hygrom.		Thermometer.			Hygrom.	
	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.	Mean Maxima.	Mean Minima.	Media.	Mean Degree of Dryness at Noon.	Mean Degree of Moisture at Noon.
January	41·0	30·8	35·9	0·3	982	33·0	25·0	29·0	0·0	1000	41·0	33·6	37·3	0·6	983	..	..	..	..	..
February . . .	46·0	33·0	39·5	1·1	963	59·1	43·8	51·4	3·6	874	48·7	34·0	41·3	6·1	804	50·0	37·0	43·5	0·0	1000
March	54·7	39·0	46·8	2·7	913	54·0	38·6	46·3	5·0	846	55·9	39·0	47·4	5·0	846	..	..	..	..	..
April	62·0	44·6	53·3	10·0	711	..	..	..	..	..	57·0	36·5	46·0	8·5	752	60·0	49·0	54·0	3·0	902
May	67·8	42·1	54·9	7·1	798	62·0	48·0	55·0	0·0	1000	..	..	..	..	..	51·0	28·0	39·5	13·0	651
June	..	..	..	..	..	74·2	52·5	63·3	12·4	664	70·6	50·8	60·7	10·8	707	74·0	47·0	60·5	14·0	673
July	..	..	..	..	..	74·0	54·0	64·0	8·3	750	78·0	53·4	65·7	11·9	684	79·0	51·5	65·2	16·0	599
August	77·6	56·0	66·8	9·1	776	76·0	59·0	67·5	10·0	724	78·0	51·6	64·8	12·9	666	70·5	50·0	60·2	6·0	826
September . . .	70·9	52·4	61·6	6·0	813	69·6	46·0	57·8	5·3	853	67·5	51·0	59·2	8·5	761	63·5	47·5	55·5	3·0	905
October	65·3	51·3	58·3	4·8	885	63·2	43·6	53·4	4·6	862	61·5	49·5	55·5	2·0	939	..	..	..	..	..
November . . .	53·6	46·6	50·1	0·6	980	51·7	38·2	44·9	2·0	938	48·5	39·1	43·8	1·6	940	50·3	28·0	39·1	5·6	938
December . . .	52·2	42·0	47·1	0·6	980	48·5	37·6	43·0	0·9	939	47·6	37·3	42·9	0·3	986	47·0	42·5	44·7	0·0	1000
Means	59·1	43·7	51·4	4·2	877	60·4	44·2	52·2	4·7	859	59·4	43·2	51·3	6·2	733	54·5	38·0	46·2	6·0	749

The dryness of the atmosphere, which proves so fatal to plants *when in a state of growth*, is, when accompanied by warmth, of the greatest importance to them *while ripening their fruit*. Together with the high temperature of the soil, it is this which causes so great a difference in the quality of the same kinds of fruit ripened in the South and the North. The excellence of Syrian Apricots is not approachable in England. The Grapes of the Mediterranean shore are only equalled in England in the best managed hothouses, when sun heat and artificial heat are skilfully employed to dry as well as warm the air, at the season of ripening. The richest and strongest wines in the world are those of Hungary, which, according to Wahlenberg, owe their excellence to the great dryness of the autumnal climate of the valley of the Theiss. Dryness of the air then, which is fatal to plants in a rapid state of growth, is in the highest degree beneficial when their functions are limited to the consolidation of tissues already formed and the elaboration of their final secretions. In the open air in England, the ripening process is usually incomplete, and hence the inability of plants from the United States, and other countries with hot autumns, to bear with us a winter far less severe than that which is natural to them.

Nothing can illustrate this truth in a more striking manner than the following statement by the late Sir Augustus Foster. Writing from Genoa he says:—"Being under the impression that single Orange or Lemon-trees, or rows and groups of Orange or Lemon-trees, might with care be brought to grow out of the ground in England like other plants, I have thought it might be worth while to mention the success which has now for several years attended a plantation that I made of seven Orange-trees in a much colder climate, in the garden of my country residence, on the hill of Turin, facing the highest range of the Alps. I was led to make the experiment from having by accident, in the first year of my arrival at Turin, seen the way in which the Orange-trees in boxes were treated in the cellars of a Piedmontese nobleman's house during winter, where they were placed for several months, without light, or heat, or water, and exposed to severe cold which almost every winter reaches to —12° or even—16° of Reaumur's thermometer (+5° to 4° Fahr.). My group of Orange-trees were taken out of boxes, and planted in earth prepared for the purpose, in the year 1826. In the very severe winter of 1828-9, three of them

perished, but not of the cold so much as the damp, for they were examined, and seen to be still safe in February, after the frost had reached above 15° of REAUMUR (—2° FAHR.), and perished a few days later from a return of the cold, attended by the drippings of a previous thaw. I had the three which died replaced, and from that time to this they have flourished and increased in size. I have them covered with a round cabin of planks, roofed with straw on the outside, at the end of October or beginning of November, and uncovered in April. They bear abundance of Oranges and Lemons, the former occasionally becoming eatable with sugar. At no other place in this country am I aware that the experiment has been tried, unprotected by a wall. But with a wall and a covering of wood and straw, to be taken off in the summer, I can scarcely doubt that the plants might be made to grow, without the clumsy accompaniment of large wooden boxes, in an English garden."

This case establishes the fact that in the north of Italy the Orange-tree bears a degree of winter cold unknown in England. For this it is prepared by the complete ripeness of its wood, a state to which it can never arrive in this climate in the open air. But are we therefore to infer that it will not live with less shelter than it now receives? Such an inference is scarcely justified, and it is worth the consideration of those who have Orange-trees at command, whether they will not pass the winter in barns, or dry out-houses, or under wooden screens where no artificial heating is applicable. Dryness in such an experiment is the first condition to secure; darkness is the second. The Orange-tree will bear to be deprived of water during the whole of its season of rest, provided its roots are kept in the earth they grew in; how much dryness, beyond this, they will bear, is shown by the long exposure to the air which they undergo in the shops of the Italian warehousemen in London; and experience tells us that the effect of cold upon plants is feeble in direct proportion to their dryness. All trees kept in the dark, or at least kept where no sun can shine upon them, will bear without injury a degree of cold which would be fatal to them if exposed, when frozen, to the direct rays of the sun. Camellias, Chinese Azaleas, Indian Rhododendrons, and many New Holland plants, take no harm in cold pits in winter, provided those pits face the north. Some of them live out of doors perfectly well during winter, if under north walls; and we have in our possession a small Orange-tree which passed the winter of 1853-4, when the thermometer fell to 4° Fahr. uninjured in a cold pit facing the north.

As to temperature in the open air, unconnected with atmospherical humidity, there seems to be no means of regulating or modifying it to any considerable extent. In some respects, however, we have even this powerful agent under our

control; but in order to exercise such control, it is necessary to understand correctly the theory of what is called RADIATION.

This cannot be better explained than in the words of Daniell. "The power of emitting heat in straight lines in every direction, independently of contact, may be regarded as a property common to all matter; but differing in degree in different kinds of matter. Co-existing with it, in the same degrees, may be regarded the power of absorbing heat so emitted from other bodies. Polished metals and the fibres of vegetables may be considered as placed at the two extremities of the scale upon which these properties in different substances may be measured. If a body be so situated that it may receive just as much radiant heat as itself projects, its temperature remains the same; if the surrounding bodies emit heat of greater intensity than the same body, its temperature rises, till the quantity which it receives exactly balances its expenditure, at which point it again becomes stationary; and if the power of radiation be exerted under circumstances which prevent a return, the temperature of the body declines. Thus, if a thermometer be placed in the focus of a concave metallic mirror, and turned towards any clear portion of the sky, at any period of the day, it will fall many degrees below the temperature of another thermometer placed near it, out of the mirror; the power of radiation is exerted in both thermometers, but to the first all return of radiant heat is cut off, while the other receives as much from the surrounding bodies, as itself projects. This interchange amongst bodies takes place in transparent *media* as well as *in vacuo;* but in the former case, the effect is modified by the equalising power of the medium. Any portion of the surface of the globe which is fully turned towards the sun receives more radiant heat than it projects, and becomes heated; but when, by the revolution of the axis, this portion is turned from the source of heat, the radiation into space still continues, and, being uncompensated, the temperature declines. In consequence of the different degrees in which different bodies possess this power of radiation, two contiguous portions of the system of the earth will become of different temperatures; and, if on a clear night we place a thermometer upon a grass-plat, and another upon a gravel walk or the bare soil, we shall find the temperature of the former many degrees below that of the latter. The fibrous texture of the grass is favourable to the emission of the heat, but the dense surface of the gravel seems to retain and fix it. But this unequal effect will only be perceived when the atmosphere is unclouded, and a free passage is open into space; for even a light mist will arrest the radiant matter in its course, and return as much to the radiating body as it emits. The intervention of more substantial obstacles will of course equally prevent the result, and the balance of temperature will not be disturbed in any substance which is not placed

in the clear aspect of the sky. A portion of a grass-plat under the protection of a tree or hedge, will generally be found, on a clear night, to be eight or ten degrees warmer than surrounding unsheltered parts; and it is well known to gardeners that less dew and frost are to be found in such situations, than in those which are wholly exposed." (*Hort. Trans.*, vi. 8).

This very important subject has received further explanation from a writer, whose words we quote, with some omissions, from the *Gardener's Chronicle* of 1853, pp. 579 and 627. The action of the sun upon all things that receive his rays is a matter of common notoriety. How important to the growth of plants, to the formation of colour and taste, to the ripening of fruit, to the consolidation of all vegetable tissues, is solar light it is needless to say. But few persons are aware of the amount of that force, or of the views of modern philosophers as to the manner in which it takes effect. We may view the surface of a lake exposed to the sun's rays during a warm summer's day, whilst the whole scene may seem to be one of the utmost tranquillity, so that we might naturally conclude that no movement of any importance was then going on. It will be found, however, that such in reality is not the case; for the rays of the sun exert a force of which we can scarcely form any adequate idea. Supposing the lake is only two miles square, it may be calculated that there will be raised from its surface in one day more than sixty-four thousand tons weight of water (64,821), by means of solar radiation. This is at least equal to the work of 10 steam-engines of 200 horse-power each for the same space of time, presuming that the above weight is only raised to an average height of between 300 and 400 feet. To balance that weight, a hill of earth would be required, 30 feet high, 100 feet wide, and 600 feet in length. In making the calculations which have led to these statements, it has been assumed that, in a hot day in summer, a quarter of an inch of water would be evaporated from an exposed surface of a lake in twelve hours, and this from an area of two miles square would amount to 2,323,200 cubic feet, which, at 62½ pounds per cubic foot, is equal to 64,821 tons. Now, a quarter of an inch is not a maximum amount of evaporation. The Comte de Gasparin observed 0·59 inch (*Gardener's Chronicle*, 1849, p. 757), and on five successive days the average exceeded half an inch. Howard, in his *Climate of London*, has recorded as much as 0·39 inch in one day. It therefore appears that 0·25 inch, that which we have assumed, is not an exaggerated quantity; on the contrary, it is but one-half of that which, according to good authorities, has been actually removed by evaporation, and under a temperature of from 73° to 75° Fahr. Instead of 64,000 tons, facts would justify us in stating that 130,000 tons might be raised in one day from a surface of water not exceeding two miles square.

Some idea may be formed from these statements of the immense

power of solar radiation in a comparatively limited space; but the many thousands of tons raised from that space do not represent the full power of the sun's rays. They merely represent weight raised, without our taking into account the force exerted in converting the water into vapour, and in that form elevating it hundreds, or it may be thousands of feet, notwithstanding the pressure of the atmosphere. In a communication on the *Mechanical Action of Radiant Heat or Light*, by Professor William Thomson, *Philosophical Magazine*, fourth series, vol. iv., p. 256, it is stated that "mechanical effect of the statical kind might be produced from the solar radiant heat, by using it as the source of heat in a thermo-dynamic engine. It is estimated that about 556 foot-pounds (that is, so many pounds raised one foot high) per second of ordinary mechanical effect, or about the work of 'one-horse power,' might possibly be produced by such an engine exposing 1800 square feet to receive solar heat during a warm summer day in this country; but the dimensions of the moveable parts of the engine would necessarily be so great as to occasion practical difficulties in the way of using it with economical advantage that might be insurmountable." This is more than twenty times the power we have assigned to the raising of water, and even this appeared so vast that until the data were thoroughly examined, the statement appeared incredible.

The same author proceeds to state that "the deoxidation of carbon and hydrogen from carbonic acid and water, effected by the solar light on the green parts of plants, is a mechanical effect of radiant heat. In virtue of this action, combustible substances are produced by plants, and its mechanical value is to be estimated by burning them, and multiplying by the mechanical value of the thermal unit. Taking from Liebig's *Agricultural Chemistry* the estimate, 2,600 pounds of dry Fir-wood, for the annual produce of one Hessian acre, or 26,910 square feet of forest land, which is at the rate of 4208 pounds or nearly 2 tons per English acre, and assuming, as a very rough estimate, 4000 thermal units centigrade as the heat of combustion of dry Fir-wood, the author finds 550,000 foot-pounds, or the work of a horse power, for 1000 seconds, as the mechanical value of the mean annual produce of a square foot of the land; and taking 50° 34′, that of Giessen, as the latitude of the locality, he estimates the mechanical value of the solar heat, which, were none of it absorbed by the atmosphere, would fall annually on each square foot of the land, at 530,000,000 foot-pounds; and infers that probably $\frac{1}{1000}$ of the solar heat which falls on growing plants is converted into mechanical effect.

"When the vibrations of light thus act during the growth of plants, to separate, against forces of chemical affinity, combustible materials from oxygen, they must lose *vis viva* to an extent equivalent to the statical mechanical effect thus produced, and therefore quantities of

solar heat are actually put out of existence by the growth of plants, but an equivalent of statical mechanical effect is stored up in the organic products, and may be reproduced as heat by burning them. All the heat of fires obtained by burning wood grown from year to year is in fact solar heat reproduced." And so, we may accordingly add, must be the heat derived from the combustion of at least the portions which have had a vegetable existence, of wood-coal and other matters.

Professor Thomson has concluded, and with reference to an equivalent conclusion by Sir John Herschel, that *heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man*. From it is derived the whole mechanical effect of animals working, water-wheels worked by rivers, steam-engines, and galvanic engines, &c. Vegetation is the great support of animal power, but vegetation could not be maintained without the action of the sun's rays, received directly or indirectly. Without such powerful evaporation caused by the sun's rays, as we have endeavoured to exemplify, the rivers would soon lose their general source. And it has been already stated that combustible materials, without which steam-power could not be generated, are stores of solar heat.

This gives some idea of the immense power of solar radiation; and within their respective spheres of action, both horticulturists and agriculturists may advantageously direct their attention to the subject. For instance, the former would avoid watering at a time, and in a manner, that would render nearly all the water he supplied liable to be carried off by evaporation before it could reach the principal roots of his plants; and the farmer, knowing the effects of radiation on a moist surface, would hesitate before he flooded say four acres with manure water, at the risk of losing a hundred tons of it, together with its portion of ammonia, by evaporation.

The same subject is taken up by the Comte de Gasparin in a communication to the Institute, printed in the *Comptes Rendus* for June, 1853. The effects, he observes, of solar radiation on vegetation are so apparent and so well known that no one doubts their importance. When one plants a Vine, he does not require scientific information to direct him in choosing a southern aspect; nor to plant fruit-trees against a wall which receives and reverberates the rays of the sun; nor to place exotic plants under glass, which readily admits direct rays of heat and light, but through which obscure heat, or that derived from a heating apparatus in a hothouse, passes slowly, and thus an accumulation of heat takes place; practical men do all these things as a matter of course. But there are many other effects resulting from the same cause, which do not come so directly under our senses. The Olive is unproductive at Agen, with a mean temperature of 57° Fahr., and fertile in Dalmatia with $55\frac{1}{2}$°; the limit of the Vine is arrested by 54° mean temperature on the banks of the Loire, but grapes ripen where the mean temperature

is only 50° on the Rhine; the harvest near London is matured with a mean summer temperature of 62°, and in the same time at Upsal with 59°. When we take these phenomena into consideration, we must conclude that they depend upon the presence or absence of that important element of heat, solar radiation, by which the temperature of opaque bodies is raised above that which they could receive from the diffused heat of the atmosphere. When we also know that the absorption and assimilation of carbon, the substance of which about half the mass of plants is composed, does not take place except under the influence of light, and is proportionate to its intensity, we feel assured that the determination of its effects must prove interesting to cultivators. Under this impression, the Comte de Gasparin made various experiments. In 1840 he communicated some observations on three Mulberry-trees, of the same variety. One of these was fully exposed to the rays of the sun, the second only till noon, and the third was wholly in the shade. The solid matter of the leaves of the first was 45 per cent. of their weight; that of the second, 36 per cent.; whilst that of the third was only 27 per cent. In 1852 he cultivated some Broad-beans on a plot of ground divided into two equal parts by a partition which shaded one half the ground from the rays of the sun. After being dried, the plants grown on the south side weighed 21 ounces; but those grown on the north side, although much taller, weighed only twelve ounces. The difference in their fructification was, however, still more remarkable. The plants on the south side had 131 pods, those on the north only 47. It is impossible to attribute these results to the simple augmentation of heat. The plants in the above experiment had a mean atmospheric temperature of $59\frac{1}{2}$° Fah. for 84 days, and $5\frac{1}{2}$° was the average daily amount of solar radiation. Certainly an additional $5\frac{1}{2}$° of obscure heat would not produce such results.

The laws indicated by Daniell plainly direct us to the means we are to employ to moderate atmospherical temperature. A screen, of whatever kind, interposed between the sun and a plant, intercepts the radiant heat of the sun, and returns it into space; and thus, in addition to the diminution of perspiration by the removal of a part of the stimulus that causes it, actually tends to lower the temperature that surrounds the plant. In like manner, the interposition of a screen, however slight, between a plant and the sky, intercepts the radiant heat of the earth; and, instead of allowing it to pass off into space, returns it to the ground, the temperature of which is maintained at a higher point than it otherwise would be. Hence it is that plants growing below the deep projecting eaves of

houses, or guarded by a mere coping of thatched hurdles, suffer less in winter than if they were fully exposed to the sky.

It is also obvious from what has been stated that plants growing upon grass will be exposed to a greater degree of cold in winter than such as grow upon gravel: but it does not therefore follow that hard gravel is, with respect to vegetation, a better coating for the surface of the ground than turf; it has its disadvantages as well as its advantages, and the former probably outweigh the latter. Its superior heating power is its only advantage; the objections to it are, its dryness in summer, and its comparative impermeability to rain, so that it causes the force of perspiration to be inversely as the absorbing power of the roots.

In Germany, where the winters are very severe, it is customary to cover the roots of plants on grass with a mulching of leaf mould, six inches deep and a foot in diameter; but this can have, I think, no sensible effect upon roots, because of the inconsiderable area that it occupies.

It is well known that blackened surfaces absorb heat much more than those of any other colour; and it has been expected that the effect of blackening garden walls, on which fruit-trees are trained, would be to accelerate the maturation of the fruit; but, notwithstanding a few cases of apparent advantage, one of which, of the Vine, is mentioned in the *Horticultural Transactions*, vol. iii., p. 330, this has been, in general, found either not to happen at all, or to so small an extent as not to be deserving of notice in practice. It is true, that so long as the wall is but little covered by the branches and leaves of a plant, the absorbent power of the blackened surface is brought into play; but this effect is lost as soon as the wall becomes covered with foliage. In the early spring before the leaves appear, the flowers are brought rather more forward than would otherwise be the case, which is in England a disadvantage. It would seem, however, that in autumn the wood becomes more completely ripened; but the effect is very slight.

It is rather to a judicious choice of soil and situation that the gardener must look for the means of softening the rigour of climate. Wet tenacious soils are found the most difficult to

heat or to drain, and they will, therefore, be the most unfavourable to the operations of the gardener; extremely light sandy soils, on the other hand, part with their moisture so rapidly, and absorb so much heat, that they are equally unfavourable. It is the light loamy soils, which are intermediate between the two extremes, that, as is well known, form the best soil for a garden. Situation is, however, of more consequence than soil, for the latter may be changed or improved, but a bad (that is, cold) situation is incurable. Cold air is heavier than warm air, and, consequently, the stratum of the atmosphere next the soil will be in general colder than that above it. When, therefore, a garden is placed upon the level ground of the bottom of a valley, whatever cold air is formed upon its surface remains there, and surrounds the herbage: and moreover, the cold air that is formed upon the sides of low hills rolls down into the valley as quickly as it is formed. Hence the fact which to many seems surprising, that what are called sheltered places are in spring and autumn the coldest. We all know that the Dahlias, Potatoes, and Kidney-beans of the sheltered gardens in the valley of the Thames, are killed in the autumn by frosts whose effects are unfelt on the low hills of Surrey and Middlesex. Daniell says he has seen a difference of 30°, on the same night, between two thermometers, placed the one in a valley, and the other on a gentle eminence, in favour of the latter. Hence, he justly observes, the advantages of placing a garden upon a gentle slope must be apparent; "a running stream at its foot would secure the further benefit of a contiguous surface not liable to refrigeration, and would prevent any injurious stagnation of the air."

One of our German translators has expressed his opinion that no such difference as 30° can have been observed, and alters the statement to 3° Reaumur! But if he had consulted Daniell's *Meteorological Essays*, Ed. 2. p. 525, he would have found that the quotation is exact. No doubt it was an extreme case; but Mr. Thompson remarked last April that at the time when fruit-buds near the ground had been universally killed by 14° of frost, they were safe on trees twenty-five to thirty feet above the level, and he believes there may have been a difference of 10°—12° in favour of even that slight height.

As a good example of the practical mode of dealing with low

situations, with a cold bottom, the following operation, described by Mr. W. Billington the elder, may be advantageously imitated:—"About the middle of June 1800, I arrived at Brocklesby, Lincolnshire, as gardener to the late Lord Yarborough. At that advanced season I found the Peach-trees in a deplorable state, with scarcely any leaves upon them, few branches, and very little fruit; the few leaves that remained were all curled or diseased, and soon after shrivelled up and fell off. The trees were not very old—about thirty years, but had extended over a fine wall without flues. The site of the garden was very unfavourable, a worse could not have been found near the mansion; for it was both low and wet. Previously to its being made into a garden, the water used to stagnate and cover a great part of it through the winter; but it had been drained at a great expense, and fresh soil had been brought in for the fruit-tree borders, &c. But after all the situation could not be essentially improved, nor the ill effects upon vegetables and tender fruit-trees entirely averted in an atmosphere so damp from the exhalations that arise in such places in the autumn and spring months, when sunny days and frosty nights are so prevalent. The fruit-tree borders had been well made and well drained; the trees had grown luxuriantly and covered the walls: but no fruit was produced of any consequence, and that was not well-flavoured, either on the walls or elsewhere. The Peaches and Apricots on walls would make efforts in the spring of each year to produce wood and leaves, *but when the cold weather prevailed, in April, May, and June, with easterly winds and frost, the leaves became diseased and curled*, and were either pulled off or fell of themselves in June or July. Thus the trees became inactive for want of healthy leaves, at the time when they should have been making and perfecting the wood for the next year's crop. But towards the end of summer, when the earth had become dry and warm to a great depth, the trees would make fresh efforts and throw out plenty of strong luxuriant shoots. Then the early autumnal frosts would set in before such late wood was half matured, so that during the winter and spring the greater part of these strong shoots was killed, and the remainder had no time to make strong flower-buds. And thus, season after season, there was nothing but disappointment, notwithstanding an immense expense: the walls were bare, the trees naked and unsightly, without fruit or with luxuriant or cankered wood. Instead of rooting out these sickly trees and planting young ones in their places that I might have the pleasure of planting and training my own trees under my own management, knowing it would be several years before there could be fruit from young trees, I was induced to consider what I could do to bring the existing trees to bear a little fruit till young trees could arrive at a bearing state, between the old ones; for nearly all the old Peaches and Nectarines were destitute of young wood half the height of the wall. Early in the autumn of the year

1800 I began with what I termed RAISING THE ROOTS (not 'root-pruning') of some Peaches and Apricots, for the latter were in as unfruitful a state as the others from the same cause. The method I devised was as follows:—First, by digging out a trench at from four to five feet from the stem of the tree, and about two feet wide, till I found the roots which were at the bottom of the good soil near three feet below the surface. This had been caused by planting too deep at first, and always digging the borders deep, which forced the roots still lower beneath the surface; but I must remark I found all the roots healthy, which showed that the disease in the branches and leaves had not affected the roots, nor been derived from diseased or cankered roots, even in that damp situation. After the earth was thrown out of the trench, we began to fork out the soil with a three-pronged fork into the open trench, throwing it out till we got all the roots bare to within eighteen or twenty inches of the stem (of course this was root-pruning, for I cut them all off to that distance), when we lifted them up and bent them backwards, if not too strong, or held them up while the soil thrown out in the operation of clearing the roots was returned into the hole, to within nine inches or a foot of the surface, treading it well down that it might not subside and admit the roots deeper than I intended. I then carefully replaced the roots upon the soil, covering them with the remainder, without adding either fresh soil or manure of any kind. When finished, the roots lay from about nine to twelve inches from the surface, instead of three feet, as before. But as the trees had been planted very deep at first, or the soil had been raised in the course of years, the extremities of the shortened raised roots were much nearer the surface after the operation than where they issued from the collar of the root; for we could not raise that part so high. My reason for doing them this way was to prevent too great a check by an entire removal or lifting them up, and I left what may be termed a good ball at the bottom of the stem undisturbed; but I took good care to hollow it well under, so as to get to every root that went perpendicular from the stem, so as to raise them up, and lay them in a horizontal position. If too strong to bend upwards, as some of them were, I cut them entirely off, but I preferred raising them up, if possible, with their extremities pointing to the surface, to prevent their making fresh roots downwards; my object was to encourage the formation of roots as near the surface as I could, conceiving it more beneficial to the trees and fruit. Afterwards I never suffered the borders to be dug above half a spit deep, my main design being to have fruit as soon as possible, and of good quality. I beg to remark I did only half a tree at once, in order to prevent its subsiding in the operation. I pursued this plan with all the Peaches and Apricots, but not in one season, because it was only an experiment I was trying. Some of the trees done in this manner were very large, particularly the Apricots, and some Pears.

"The first year after the operation I had the secret pleasure of seeing my trees make healthy shoots, from nine to fifteen inches long, without any thick, curled leaves. *The first shoots and leaves that were made were not injured as previously*, but continued healthy all through the spring and summer, ripening their wood early in the autumn, and forming fine blossom-buds for the ensuing season; and what fruit appeared was earlier than usual by three weeks, with an excellent flavour, equal to any on a hot wall. The year after the operation we had plenty of fine fruit, early and well-flavoured. *I did not think so much of finely-trained trees, pruned, and nailed according to the rules of the art, as of seeing a wall well covered in the season*, when the proprietor expects to find something more substantial than a smart appearance; I trained the young shoots in any direction I could lay them in, so as to cover the bare spaces. After the first years I had more Peaches and Apricots large and well-flavoured than could be well consumed by the family. I tried the same experiment upon other kinds of fruit-trees, especially Pears, with the same success; and I also planted a great number of young fruit-trees of various kinds on 'prepared bottoms,' to prevent the roots getting too deep in such an unfavourable situation, where nearly all the first-planted trees had failed, become cankered, and were rooted out, having never produced fruit fit to send to table. Had I continued in his lordship's service, I intended, after the roots had extended over those prepared bottoms, and struck down into the damp ungenial subsoil, to have shortened and raised them again to the outsides of these prepared bottoms, which were from four to five feet in diameter for the dwarf trees in the borders by the sides of the main walks, and about the same diameter for the trees against the walls. I prepared my young trees for such planting by having them for a year or two in the garden, so as to have long roots to spread horizontally, when I finally planted them out on the prepared bottoms, taking especial care afterwards not to dig deep over the roots. The materials of which the prepared bottoms were formed consisted chiefly of broken bricks, tiles, cinders, and slags from the hothouse furnaces or fire-places, with lime crops or riddlings over all, firmly rammed down hard, from eighteen to twenty-four inches thick, with about a foot of good soil over them, and elevated a little in the centre to plant them on."

This experiment seems to have laid the foundation of the modern system of root-pruning, and root-raising, when fruit-trees are doomed to grow in places unsuited to them.

It has been said that, to obtain the most favourable conditions of climate in this country, a garden should have a south-eastern exposure. This, however, has been recommended, I think, without full consideration. It is true that in

such an exposure the early sunbeams will be received; but, on the other hand, vegetation there would be exposed to several unfavourable actions. There would be little protection from easterly winds, which, whether south-east or north-east, are the coldest and driest that blow: in the next place, an exposure to the first sun of the morning is very prejudicial to garden productions that have been frozen by the radiation of the night; it produces a sudden thaw, which, as gardeners well know, (see *Hort. Trans.*, iii. 43.) causes the death of plants which, if slowly thawed, would sustain no inconvenience from the low temperature to which they had been exposed.

The following well authenticated cases will exemplify this important practical truth. 1. In the early spring of 1846, a quantity of Geraniums, and other soft-wooded plants, were conveyed some twenty miles by waggon on a frosty night, and not being properly protected were completely frozen when they arrived at their destination, by daylight in the morning. So much were they frozen, that the succulent tops for several inches were apparently masses of ice, and the greater part of the leaves had suffered more or less. The whole of these plants were quickly removed to a dark cellar; and a covering of mats, supported by a temporary frame-work, was thrown over them. Water, just above the freezing temperature, was freely applied to the foliage, and no light admitted for twenty-four hours. On removing them, scarcely a leaf had suffered, except such as had been bruised in the unpacking. 2. One night, in mid-winter, the person in charge of a conservatory forgetting to apply the necessary artificial temperature, found on entering the house at 4 o'clock in the morning, that the tender plants were much frozen. He applied fire to the boiler, raised the temperature a degree or two above freezing, and then liberally applied cold water with a syringe. The result was that nothing beyond a few leaves or a stray shoot sustained any damage. 3. A house of Pelargoniums was penetrated by frost, the plants much frozen, and the frost on the increase when the circumstance became known in the morning. Cold water was in this case applied, but without the precaution of raising the temperature above freezing. The result was that the water, as soon as it fell on the foliage, became ice. The more water the greater evil. This detected, a fire was lighted, and the necessary temperature acquired, when the result was all that could be wished. Sunlight was prevented reaching the plants until their fluids were once more in motion.—A sudden thaw is easily obviated, by syringing frozen plants with cold water a few degrees above 32°. Mr James Cuthill mentions the following occurrence in illustration of this: "In the spring

of 1826, or 1827, when I resided at 'the Cedars' at Putney, the only border which my next door neighbour and myself had for growing early Peas, had an east aspect. A very severe frost (10°) came over that district about the 15th of May. The Peas were in full bloom on my neighbour's border, as well as mine. I syringed all mine with cold water. My neighbour, on witnessing the operation, said that he would not kill his in that way. I saved all mine, he lost all his. This taught me a lesson which I never forgot; and by the same means I have often saved the Peach, Pear, and other fruits, as well as Gooseberries, after they were a good size." It is to be remembered, however, that this plan is serviceable only in the case of morning frosts of short duration.

In our glazed houses, we have full control over the state of the atmosphere, as regards both its moisture and temperature, by means familiar to every gardener; but the manner of applying those means, and the causes that oppose their action, deserve to be the subject of inquiry.

It will have been seen, from what has been already stated upon that subject, that in general, in warm countries, the air is occasionally at least, if not permanently, filled with vapour to a much greater extent than in northern latitudes*, and, as in our glazed houses we cultivate exclusively the natives of warm countries, it is also obvious that, as a general rule, the air of such houses requires, at certain periods, to be damper than that of the external air. Those periods are when vegetation is most active. On the other hand, countries nearer the equator are subject to seasons of dryness, the continuance of which is often much greater than any thing we know of here in the open air, and consequently artificial means must also be adopted to bring about, in glazed houses, that state of things at particular periods; namely, those of the repose of plants. These facts afford abundant proof of the necessity of regulating the moisture of the atmosphere with some certainty.

The dampness of glass-houses is easily maintained at any required degree by various contrivances: such as inundating

* "Captain Sabine, in his meteorological researches between the tropics, rarely found at the hottest period of the day so great a difference as 10° between the temperature of the air and the dew-point; making the degree of saturation about ·730, but most frequently 5° or ·850; and the mean saturation of the air could not have exceeded ·910." (*Daniell.*)

the floors and flues, which is one of the best means of supplying the atmosphere with a steady supply of elastic vapour; or by discharging steam into a house, by open tanks of water resting on pipes or flues; or by syringing, which not only throws moisture into places not easily reached by other means, but disturbs the numerous insects which infest such places, and removes the dust and honey-dew which accumulate in the absence of natural rain. The immense importance of the last of these results has been fully explained at pages 58 and 59.

It will be evident that syringing is an imitation of rain or dew; of rain when water is dashed violently upon leaves; of dew when it is forced through fine roses and gently deposited upon leaves. Gardeners confound the two operations under one common name; but it would be better, as I have suggested elsewhere, if the term SYRINGING were confined to the imitation of rain, and the more gentle method were denominated BEDEWING. The French call the latter *bassinage*. In this, as in all things else, the operations of Nature should be imitated with all the exactness possible; we may be certain that what we call Nature is right, and that we, when we neglect her precepts, are wrong. Dew is not deposited in the morning or at noon; therefore bedewing at noon or in the morning is to be carefully avoided. Dew falls in the evening, clings to plants during the night, disappears as the sun gains power. Bedewing, then, should be effected in the evening, and in such abundance that it may remain for dispersion by the returning sun. This is opposed to the practice of the older gardeners, but its fitness is shown by such considerations as the following:—

When plants are bedewed at night, no perspiration is going on; all the surface is engaged in absorption. In this way the loss of fluid by day is virtually repaired. During the dark hours the tissues absorb the moisture in contact with them; drooping leaves straighten, bending stems stand once more erect, and the very hairs that clothe the surface of a leaf, on which they lay relaxed at sun-down, presently fill, stiffen and rise up, and drink till they can drink no more, the limpid fluid at last hanging in drops from their gorged points. Were it otherwise, vegetation would perish in the autumn, however vigorous it might have been during the summer; for in autumn the earth is exhausted of its moisture, and plants feed chiefly by their green surfaces. Each returning sun expels from a plant more fluid than the earth can possibly supply; but the waste is amply made up by the dews which act from sunset to sunrise. What occurs out of doors also occurs in a hothouse, so far as waste of fluid is concerned; but in a glasshouse there is little or no restoration at night, because dew will not form beneath a roof, and therefore the process of artificial bedewing

becomes indispensably necessary. There is no doubt that bedewing by day does more harm than good. Experience shows that when plants are so treated they lose their verdure and become yellow, especially if the sun shines on them immediately after the operation. It cannot be useful, for it dries up before it can be absorbed. It must do harm; because the rapid evaporation from the surface of a wet leaf under a bright sun is attended by a degree of cold which paralyses the vitality of the leaf itself. When rain falls by day the sky is overcast; or if we have a rainstorm in sunshine the occurrence is casual and the effect is transient, but in a hothouse so mismanaged a gardener has to encounter the consequence of a continually recurring bad effect.

But there are some circumstances, easily overlooked, which interfere very seriously with this power, and which, it will be conceived, may reduce it very much below the expectations of the cultivator. The most unsuspected of these is the destruction of aqueous vapour by the hot, dry, absorbent surface of flues. The advantages of hot-water pipes over brick flues arises in great measure from the former not drying the air. Gardeners explain the difference in the action of the two, by saying that the dry heat produced by hot-water pipes is *sweeter* than that given off by flues; which is not a very intelligible expression. The fact is, that, in houses heated by flues, the soft burnt clay of the brick flues robs the air of its moisture, while the unabsorbent surface of iron pipes abstracts nothing.

Another source of dryness is the coldness of the glass roof, especially in cold weather, when its temperature is lowered by the external air, in consequence of which the moisture of the artificial atmosphere is precipitated upon the inside of the glass, whence it runs down in the form of "drip." Daniell observes that the glass of a hot-house, at night, cannot exceed the mean of the external and internal air; and, taking them at 80° and 40°, 20° of dryness are kept up in the interior, or a degree of saturation not exceeding ·528. To this, in a clear night, we may add at least 6° for the effects of radiation, to which the glass is particularly exposed, which will reduce the saturation to ·424; and this is a degree of drought which must be destructive. It will be allowed that this is by no means an extreme case, but one that must frequently occur during the winter season. Some idea, he adds, may be formed of the

prodigiously increased drain upon the functions of a plant, arising from an increase of dryness in the air, from the following consideration:—If we suppose the amount of its perspiration, in a given time, to be 57 grains, the temperature of the air being 75° and the dew-point 70°, or the saturation of the air being ·849, the amount would be increased to 120 grains in the same time, if the dew-point were to remain stationary, and the temperature were to rise to 80°; or, in other words, if the saturation of the air were to fall to ·726. (*Hort. Trans.*, vi. 20.) It is well known that the effect of maintaining a very high temperature in hot-houses at night, during the winter, is frequently to cause the leaves to wither and turn brown, as if scorched or burnt; and this is certainly owing to the dryness of the air, in consequence of the above causes.

Nothing perplexes inexperienced gardeners more than this unsuspected source of mischief, which is of constant occurrence in Vineries supposed to be managed with the utmost skill. When a gardener is told that it is of little use to pour water into a tub with a hole in the bottom, for that in a few minutes the tub will be as dry as if it had received no water at all, he admits the truth of the observation. But if he is assured, that the more he heats and damps a Vinery the drier it will become, he will lend a less ready acquiescence; and yet, in cold weather, the one assertion is as true as the other.

When Vine leaves are young they are always thin, and imperfectly formed; they are in that state where any unfavourable circumstances are more likely to take effect upon them, than if they were hard and fully formed, especially if they come out of Vineries carefully managed, with plenty of heat and moisture by day, and more, if there is any difference, at night. All is right on some eventful day, let us say the 3rd of February; the house is locked up; there is a clear moon and a bright sky, with every sign of a hard frost, and therefore the fires are looked to; and the Vinery is duly visited at midnight. It is impossible that anything can go wrong. Next day, the 4th of February, the leaves are not so green as they were before; by night they are unmistakeably brown; and on the 5th half are evidently dead. "How is this?" "Oh!" it is said, "the 4th was a bright sunny day, and the leaves were sunburnt." This answer is considered satisfactory; blinds are provided against another year. When February comes they are drawn down every sunny day, and withdrawn at night. But the leaves are tenderer than ever, and another disaster befalls them; they are again burnt worse than before. The sun then cannot be in fault. A flue

must have leaked; and gas must have escaped into the house; yet the house is warmed with water in pipes. In that case, it must have been something from the pipes; or a hole must exist between the inside of the Vinery and the furnace, or the stoke-hole. Finally it is suspected that the Vines must be poisoned by something in the soil, or in the water. But in all such cases the injury proceeds from dryness and nothing else.

If a piece of cold glass is introduced into a warm damp room, moisture, in the form of dew, is immediately formed upon the glass. This moisture previously existed in the form of elastic vapour; and the dew that forms on the glass is at the expense of the vapour surrounding it; so that if a cubic body of such vapour be represented by 1000, and 250 parts of it be abstracted by precipitation, or condensation, upon the cold glass, it is clear that there will be only 750 parts left; in other words, the air will be one-quarter drier after the introduction of the cold glass than it was before. Now, if we suppose that this abstraction of vapour were carried to its utmost limits, it is evident that the end would be the total drying of the air, in consequence of the condensation of all its vapour on the surface of cold glass. The Vine leaf, when young, will not bear an atmosphere the degree of saturation of which is much below 800. If the saturation falls to 500, it will be dried up and perish. This being so, the force of Daniell's remarks will be obvious. And when it is considered that a temperature at night of 20° is no very unfrequent occurrence in this country when *the saturation of the air may fall to* 120°, that is to say, instead of the atmosphere surrounding Vine leaves amounting to 7 or 8 parts in 10, which is what they require, it may not amount to more than $1\frac{1}{4}$ in 10, which is fatal to them, the amount of the danger becomes still more striking:— Thus, in an atmosphere of heat and moisture, the Vine leaves may actually die of drought; and that this occasionally happens, and is a frequent though unsuspected cause of injury to tender foliage, near a glass roof, is perfectly certain.

It is evident that the mode of preventing this drying of the air by the cold surface of a glass roof will be, either by raising the temperature of the glass, which can only be effected by drawing a covering of some kind over our houses at night, so as to intercept radiation, or by double glass sashes; or else by keeping the temperature of the air of the house as low as possible, consistently with the safety of the plants, and so diminishing the difference between the temperature of the external and internal air.

The objections to external coverings are, 1st, their expense, and, 2nd, the trouble attending them. If, however, the needless cost of fuel, and the injury sustained by plants, be placed in one scale, and the expense

of an external covering in the other, it would be found that the balance would turn in favour of the latter. The trouble of covering a house with mats, every night, is no doubt the main obstacle to their employment. Long ago, Sir Joseph Paxton used moveable thatched roofs running in a sort of groove or rail, capable of being pushed over a house every night, and pushed off again at one end every morning; and this device left nothing to be desired in principle. But it demanded space. For every fifty feet run of glass house fifty more feet were required at the end of it to receive the moveable roof during the day, and it is only here and there that so much space can be afforded. Nor is the plan applicable at all to houses of any considerable dimensions. It therefore still remains for some ingenious person to show how glass houses may be covered every night *cheaply*, and *without trouble*, by a moveable roof.

It is to the attention that, since the appearance of Daniell's paper, in 1824, upon this subject, has been paid to the atmospherical moisture of glazed houses, that the great superiority of modern gardeners over those of the last generation is mainly to be ascribed: there are, however, traces of the practice at a much earlier period, although, from not understanding its theory, no general improvement took place. In the year 1816, an account was laid before the Horticultural Society of a successful mode of forcing Grapes and Nectarines, as practised by Mr. French, an Essex farmer, with rude materials, and under unfavourable circumstances. It is not a little remarkable, that, although Mr. French himself correctly referred his success to the skilful management of the atmospherical moisture of his forcing-houses, the subject was so little understood at that time that the author of the account not only shrank from adopting the opinion, but evidently, from the manner in which he speaks of the explanation, had no idea of its justness.

"About the beginning of March, Mr. French commences his forcing by introducing a quantity of new long dung, taken from under the cow-cribs in his straw yard; being principally, if not entirely, cow dung; which is laid upon the floor of his house, extending entirely from end to end, and in width about six or seven feet, leaving only a pathway between it and the back wall of the house. The dung being all new at the beginning, a profuse steam arises with the first heat, which, in this stage of the process, is found to be beneficial in destroying the ova of

insects, as well as transfusing a wholesome moisture over the yet leafless branches; but which would prove injurious, if permitted to rise in so great a quantity when the leaves have pushed forth. In a few days, the violence of the steam abates as the buds open, and in the course of a fortnight the heat begins to diminish; it then becomes necessary to carry in a small addition of fresh dung, laying it in the bottom, and covering it over with the old dung fresh forked up: this produces a renovated heat, and a moderate exhalation of moist vapour. In this manner the heat is kept up throughout the season, the fresh supply of dung being constantly laid at the bottom in order to smother the steam, or rather to moderate the quantity of exhalation; for it must always be remembered that Mr. French attaches great virtue to the supply of a reasonable portion of the vapour. The quantity of new dung to be introduced at each turning must be regulated by the greater or smaller degree of heat that is found in the house, as the season or other circumstances appear to require it. The temperature kept up is pretty regular, being from 65 to 70 degrees." (*Hort. Trans.*, i. 245.)

In this case, which attracted much attention at the time, it is evident that the success of the practice arose principally out of two circumstances: firstly, the moisture of the atmosphere was skilfully maintained in due proportion to the temperature; and, secondly, a suitable amount of bottom heat was secured. This is, as will be elsewhere remarked, the principal cause of the advantages found to attend the Dutch mode of forcing. The reporter upon Mr. French's practice speaks with surprise of the rudeness of the roof of his forcing-houses, and of the numerous openings into the air through the laps of the glass and the joints of the sashes; but these were points of no importance under the mode of management adopted.

The impossibility of preserving any plants, except succulents, in a healthy state, for any long period, in a sitting-room, is evidently owing to the impracticability of maintaining the atmosphere of such a situation in a state of sufficient dampness.

An excess of dampness is indispensable to plants in a state of rapid growth, partly because it prevents the action of perspiration becoming too violent, and partly because under such circumstances a considerable quantity of aqueous food is absorbed from the atmosphere, in addition to that obtained by the roots. But it is essential to observe that, when not in a

state of rapid growth, a large amount of moisture in the air will be prejudicial rather than advantageous to a plant; if the temperature is at the same time high, excitability will remain in a state of continued action, and that rest which is necessary will be withheld, the result of which will be an eventual destruction of the vital energies. But, on the other hand, if the temperature is kept low while the amount of atmospherical moisture is considerable, the latter is absorbed, without its being possible for the plant to decompose it; the system then becomes, in the younger and more absorbent parts, distended with water, and decomposition takes place, followed by the appearance of a crop of microscopical fungi; in short, that appearance presents itself which is technically called "damping off."

A skilful balancing of temperature and moisture in the air, and a just adaptation of them to the various seasons of growth, constitute the most complicated and difficult part of a gardener's art. There is some danger in laying down general rules with respect to this subject, so much depending upon the peculiar habits of species, of which the modifications are endless. It may, however, I think, be safely stated that the following maxims deserve especial attention :—

1. Most moisture in the air is demanded by plants when they first begin to grow, and least when their periodical growth is completed.

2. The quantity of atmospheric moisture required by plants is, *cæteris paribus*, in inverse proportion to the distance from the equator of the countries which they naturally inhabit.

3. Plants with annual stems require more than those with ligneous stems.

4. The amount of moisture in the air most suitable to plants at rest is in inverse proportion to the quantity of aqueous matter they at that time contain. (Hence the dryness of the air required by succulent plants when at rest.)

CHAPTER IV.

OF VENTILATION.

It is probable that no horticultural question has excited more difference of opinion than that of ventilating glass-houses. On the one hand it has been contended that plants in such places require no more air than will necessarily be introduced through crevices, sashes, and doors; on the other it has been insisted by gardeners of great experience that plants require an incessant and abundant supply of fresh air in motion.

Those who support the latter view point to the facts that meet the observer at every step in wild nature, where plants are to be found in the most vigorous health. In the open air the atmosphere that surrounds them is incessantly in motion, even in the calmest day; and by evening or during the night, *when they most especially are feeding*, in rapid motion. The atmosphere is their pasture, and its ever-varying density is a natural phenomenon most intimately connected with the maintenance of vegetable health. It is a beautiful compensation for their want of locomotion; as plants cannot move to the atmosphere, the atmosphere is ever moving towards them. It is therefore certain, without inquiring into the exact philosophy of the matter, that free access to abundant air must be secured, if the health of plants in glass-houses is to equal that in the open air.

On the other hand the advocates of a confined atmosphere believe that those who attach so much importance to ventilating houses abundantly, scarcely consider the nature of plants, and suppose that they require to be treated like man himself, thus consulting their own feelings rather than the laws of vegetable growth. It is true that animals require a continual renovation

of the air that surrounds them, because they speedily render it impure by the carbonic acid given off, and the oxygen abstracted by animal respiration. But the reverse is what happens to plants; they exhale oxygen during the day, and inhale the carbonic acid of the atmosphere; and, considering the manner in which glass-houses are constructed, the buoyancy of the air in heated houses will enable it to escape in sufficient quantity to renew itself as quickly as can be necessary for the maintenance of the healthy action of the organs of vegetable respiration. It, therefore, is improbable that the ventilation of houses in which plants grow is so necessary to them as is supposed. So it is said.

There can, however, be no doubt that the latter argument is fallacious, and that gardeners who judge of the requirements of plants by their own, are not so much in error as has been supposed. It is true that ventilation is not required in order to supply plants with food enough to maintain existence; they get from tranquil air as much gaseous food as will support life. But it is one thing to exist, and another to thrive. Moreover, the admission of abundant air is not merely for the purpose of feeding a plant; it enables it to perspire copiously, a function not less indispensable than feeding, for perspiration with plants is only a part of the process of digestion. Let us only watch the effect of allowing a continual change of air to take place among plants in a greenhouse. The best managed house within our knowledge, in which the plants are always dark green, short jointed, and loaded with flowers, is one with a span roof, the lower half of which is moveable and the upper fixed; by raising or lowering the lower sashes a strong current of air can at all times be carried through the plants, among which it incessantly plays. In this place there are no yellow leaves, no mildew, no spot, no languor, no fogging off. At Sion the Clove has borne flowers, the Litchi and Nutmeg ripened their fruit with all their natural aroma, and the Mangosteen is growing as if at Batavia; this has been effected in a stove so constructed as to secure the presence of constant currents of air. The Mango has never flourished more than it did at Walcot, in the days of the late Lord Powis;

it grew there in a house in which air was necessarily in constant and very rapid motion. The best flavoured Grapes are ripened out of doors; no one would compare our hot-house Grapes for flavour with those of the climates where they ripen naturally. The best coloured Grapes are ripened out of doors; no one ever saw ripe black Grapes deficient in colour in the open air. The best Peaches, Strawberries, Apricots, are ripened in the open air. The best flavoured Queen Pine I ever tasted was one ripened at Bicton in the open air.*

It is not improbable that one of the advantages of ventilation depends upon a cause but little adverted to, but which certainly requires to be well considered. It was an opinion of Mr. Knight, that the motion given to plants by wind is beneficial to them by enabling their fluids to circulate more freely than they otherwise would do; and in a paper printed in the *Philosophical Transactions* for 1803, p. 277, he adduces, in support of his opinion, many experiments and observations; of which the following is sufficiently striking:—

> "The effect of motion on the circulation of the sap, and the consequent formation of wood, I was best able to ascertain by the following expedient. Early in the spring of 1801, I selected a number of young seedling Apple trees, whose stems were about an inch in diameter, and whose height between the roots and first branches was between six and seven feet. These trees stood about eight feet from each other; and, of course, a free passage for the wind to act on each tree was afforded. By means of stakes and bandages of hay, not so tightly bound as to impede the progress of any fluid within the trees, I nearly deprived the roots and lower parts of the stems of several trees of all motion, to the height of three feet from the ground, leaving the upper part of the stems and branches in their natural state. In the succeeding summer, much new wood accumulated in the parts which were kept in motion by the wind; but the lower parts of the stems and roots increased very little in size. Removing the bandages from one of these trees in the following winter, I fixed a stake in the ground, about ten feet distant from the tree, on the east side of it; and I attached the tree to the stake at the height of six feet, by means of a slender pole, about twelve feet long; thus leaving the tree at liberty to move towards the north and south, or, more properly, in the segment of a circle, of which the

* See p. 101. The author regrets to see that the name of Lady Rolle is misprinted Rolfe, at that place.

pole formed a radius; but in no other direction. Thus circumstanced, the diameter of the tree from north to south in that part of its stem which was most exercised by the wind, exceeded that in the opposite direction, in the following autumn, in the proportion of thirteen to eleven."

Now, if the effect of motion is to increase the quantity of wood in a plant, it is evident that ventilation, which causes motion, must tend to produce a healthy action in the plants exposed to it; and such a state must also be favourable to the development of all those secretions upon which the organisation of flowers, the setting of fruit, and the elaboration of colour, odour, flavour, &c., so much depend. Some suggestions by Mr. Knight, as to the manner in which this result can be artificially produced, will be found in the *Hort. Trans.*, vol. iv. p. 2. and 3. (See also *Hort. Trans.*, new series, i. 34.)

It is not a little remarkable, however, that the same great gardener as well as physiologist should have expressed himself unfavourable to abundant ventilation. It would seem as if he scarcely perceived the whole bearing of the interesting experiment just recorded. It may be objected, he says, that plants do not thrive, that the skins of Grapes are thick, and other fruits without flavour, in crowded forcing-houses: but in these it is probably light, rather than a more rapid change of air, that is wanting; for, in a forcing-house which I have long devoted almost exclusively to experiments, I employ very little fire heat, and never give air till my Grapes are nearly ripe, in the hottest and brightest weather, further than is just necessary to prevent the leaves being destroyed by excess of heat. Yet this mode of treatment does not at all lessen the flavour of the fruit, nor render the skins of the Grapes thick; on the contrary, their skins are always most remarkably thin, and very similar to those of Grapes which have ripened in the open air. (*Hort. Trans.*, ii. 225.)

Mr. Knight would not even admit that in forcing-houses ventilation is useful at the period of ripening; but the following extract, in which this opinion is expressed, shows that he did not use the word ventilation in its ordinary sense. "A less humid atmosphere is more advantageous to fruits of all kinds, when the period of their maturity approaches, than in the earlier stages of their growth; and such an increase of

ventilation, at this period, as will give the requisite degree of dryness to the air within the house, is highly beneficial, provided it be not increased to such an extent as to reduce the temperature of the house much below the degree in which the fruit had previously grown, and thus retard its progress to maturity. The good effect of opening a Peach-house, by taking off the lights of its roof during the period of the last swelling of the fruit, appears to have led many gardeners to overrate greatly the beneficial influence of a free current of air upon ripening fruits; for I have never found ventilation to give the proper flavour or colour to a Peach, *unless that fruit was, at the same time, exposed to the sun without the intervention of glass;* and the most excellent Peaches I have ever been able to raise were obtained under circumstances where change of air was as much as possible prevented, *consistently with the admission of light* (*without glass*), to a single tree." (*Hort. Trans.*, ii. 227.)

This remark makes it evident that Mr. Knight used the word ventilation in the sense of a draught or current of air; for it is difficult to conceive how plants can be more abundantly supplied with fresh air than by removing the glass sashes which obstructed its admission.

It is not merely in heated houses or during the summer season that free ventilation is required. It is just as necessary in winter, or when plants are torpid. We cannot suppose that the substances contained within the living bark are at rest during half the year, because the leaves have fallen away. On the contrary, the change of colour which gradually takes place in branches during winter, is proof enough that chemical action is still going on in obedience to vital force. It is inconceivable that such actions should be unconnected with the atmosphere that surrounds the branches, although chemists may be unable to explain the connection; and without waiting for the rationale, we may assure ourselves that those motions of the air which are so indispensable in summer are at least as much needed in winter; perhaps more so.

As to cold pits and cold greenhouses, they require that their air should be kept in motion just as much as that of heated

structures. If we only look at the plants discovered when mats are removed from pits which have long been closely covered up during a tedious winter, dropping limb from limb, covered with mouldiness, musty and rotten, instead of the healthy specimens originally placed there, we shall require no argument to show that ventilation in winter is as necessary as in summer, and in cold pits as well as heated buildings. If this is indispensable when plants are in a state of torpor, how much more is it needed in such places as dung-pits or frames, especially where salad, cucumbers, and similar plants are grown. In those cases the object is in part to dry the air, in order that the plants may not absorb more aqueous particles than they can decompose and assimilate. Although plants of this kind will bear a high degree of atmospherical moisture in summer, when the days are long and the sun bright, and when, consequently, all their digestive energies are in full activity, yet they are by no means able to endure the same amount in the short dark days of winter, when, from the want of light, their powers of decomposition or digestion are comparatively feeble.

One of the causes of success in the Dutch method of winter forcing is, undoubtedly, their avoiding the necessity of winter ventilation, by intercepting the excessive vapour that rises from the soil, and which would otherwise mix with the air. For this purpose they interpose screens of oiled paper between the earth and the air of their houses, and in their pits for vegetables they cover the surface of the ground with the same oiled paper, by which means vapour is effectually intercepted, and the air preserved from excessive moisture.

It is highly probable, if not yet proved, that the true cause of the difficulty of cultivating alpine plants in the lowlands, arises from the impossibility of maintaining around them a damp atmosphere associated with low temperature, and the copious evaporation caused by the rapid currents of air to which they are exposed in their native stations. Some plants indeed are able to dispense with these conditions, and live indifferently in elevated regions and on plains; of which the common Shepherd's Purse (*Capsella*) and *Cardamine hirsuta* are Indian examples quoted by Dr. Hooker; but the majority can

only exist under those peculiar conditions in which they have been placed by nature.

This explanation of a well known horticultural difficulty seems better to agree with facts than the suggestion of Baron Humboldt, to which I formerly assented, that diminished atmospheric pressure was the cause. On this point Dr. Hooker has remarked that "a comparison of Arctic vegetation with that of elevations of 17,000 feet, where literally fifteen inches of pressure are removed, shows no difference in the characters or habits of such plants as are common to both regions; it certainly induces no peculiarity of vegetation, or there would be a character common to the Alpines of India and of America which the temperate and Arctic regions should not share; but though the Alpine floras of these tropical regions widely differ from each other, they are both Arctic floras in the greatest degree, generically."

In his *Himalayan Journals* this distinguished traveller has some additional observations, which deserve quotation. "It has long been surmised that an Alpine vegetation may owe some of its peculiarities to the diminished atmospheric pressure; and that the latter, being a condition which the gardener cannot supply, he can never successfully cultivate such plants in general. I know of no foundation for this hypothesis; many plants, natives of the level of the sea in other parts of the world, and some even of the hot plains of Bengal, ascend to 12,000 and even 15,000 feet on the Himalaya, unaffected by the diminished pressure. Any number of species from low countries may be cultivated, and some have been for ages, at 10,000 to 14,000 feet, without change. It is the same with the lower animals; innumerable instances may with ease be adduced of pressure alone inducing no appreciable change, whilst there is absence of proof to the contrary. The phenomena that accompany diminished pressure are the real obstacles to the cultivation of Alpine plants, of which cold and the excessive climate are perhaps the most formidable. Plants that grow in localities marked by sudden extremes of heat and cold, are always very variable in stature, habit, and foliage. In a state of nature we say the plants 'accommodate themselves' to these changes, and so they do within certain limits; but for one that survives of all the seeds that germinate in these inhospitable localities, thousands die. In our gardens we can neither imitate the conditions of an Alpine climate, nor offer others suited to the plants of such climates." (Vol. ii., p. 415.)

The notorious difficulty of cultivating some of the Sikkim Rhododendrons is probably to be explained by similar considerations. In the Sikkim Himalaya there is little continued sunshine, and the warm air is perpetually charged with moisture brought by the southerly winds, which discharge it to the extent of 120 to 140 inches annually (*Hooker*). There appears to be no means of imitating such a state of things artificially. We may secure the temperature, and we may load warm air with vapour, but when we attempt to set the latter in active motion, the humidity disappears.

To the reasons already offered for regarding free ventilation as a necessary condition of high cultivation, may be added the importance of removing deleterious matters, such as sulphurous acid, or of diluting those which, like carbonate of ammonia, sulphuretted hydrogen, hydrochloric acid, &c. are only wholesome when administered in quantities almost if not entirely inappreciable by the senses.

We know too little of the effects of volatilised corrosive sublimate, to say whether free ventilation would not prevent the destructive action of that agent upon plants kept in greenhouses built of *Kyanised wood.*

It has been thought that an irresistible argument against the need of free ventilation is to be found in the moveable structures called Wardian Cases, in which it is alleged that plants grow luxuriantly although cut off as far as possible from all access to air. But in reality such contrivances are not at all suited for the cultivation of plants; they are only applicable to their preservation for limited periods of time. It was the success that attended the latter which led gardeners to suppose Ward's Cases equally well suited to the former, and to fall into the error of disbelieving in the necessity of free ventilation.

As the Wardian Case is largely employed in Horticulture, especially in the decoration of sitting-rooms, it seems desirable to point out in this place what are its real merits and defects.

When Mr. Ward first remarked a Grass and a Moss growing inside a damp bottle, he merely saw what gardeners had witnessed for a couple of centuries at least. He beheld the propagator's bell-glass with its

edges dipping into wet sand—a close cavity, with transparent sides, and an interior possessing an uniform and unchangeable degree of humidity. Thirty or forty years since, and probably long before, the same principle was employed in the drawing-rooms of the wealthy for the preservation of the freshness of cut flowers: the flowers were placed in a vase; the vase stood in water, and a bell-glass, dipping its edges into the water, covered the whole. There is not the smallest difference in principle between these old contrivances and the modern Wardian Case. But all such plans were merely preservative; no one thought of cultivating plants in close cases, though they found the latter invaluable for keeping plants alive. A cutting under a bell-glass was surrounded with moist air until it had formed roots; but the moment the action of roots was secured it was transferred to the open air. What Mr. Ward did, when he proposed the case that bears his name, was to contrive a large portable bell-glass and its supporter, made of materials strong enough to bear the rough usage of a sea voyage. He demonstrated the defects of the old travelling greenhouses, and suggested a remedy, pointing out at the same time upon what principles the remedy depended. That principle was—1st, to expose plants to light, and—2nd, to ensure their being constantly surrounded by a medium damp enough to keep their system in a state of activity. The old travelling greenhouses, or plant cases, were open at the joints, and the water originally contained in them quickly evaporated, leaving a mass of parched earth in which no vegetation could long survive; they were also glazed with talc, or oyster shells, or other half-opaque materials, through which no such amount of light could pass as plants require for the preservation of their vitality.

When properly constructed, the Wardian Case answers perfectly as a means of transporting plants to great distances. It also has its value in places where the air is filled with floating soot or dust; or where it is naturally too dry for vegetation, as in sitting-rooms. There the lives of certain kinds of plants may be maintained for a long period of time, with the appearance of health; shade-loving races, such as Ferns and Mosses, will even thrive there; and others, like dry Crocuses and Hyacinths, which have been previously made ready by the usual processes, out of doors, may be led to blossom in perfection for a season, or in some instances for more.

It is asserted indeed that plants have been known to grow well, and flourish in Wardian Cases. To that statement I lend an incredulous ear. It will be always found, upon inquiry, that such cases are opened daily and ventilated freely, and thus, or otherwise, relieved from the moisture with which the air is saturated. But those are not Wardian Cases at all; they are merely greenhouses on a small scale, in which plants grow well or ill, according to the care and skill with which they are managed. A Wardian Case demands neither care nor skill; its

operation is essentially automatic; it is its own gardener in every way. The moment its structure enables the possessor to give it daily attention—in short, to cultivate the plants within it, it ceases to be Wardian, and may as well be called by any other name, as has been already shown. Plants cannot be cultivated well in the absence of free access to air in motion. The more rapid the motion, within certain limits, the higher the health of plants, and *vice versâ.* This is the foundation of good gardening; and it is precisely this which is unattainable in a Wardian Case. The latter is the opposite of a natural condition; but plants demand all the resemblance to natural conditions which is to be secured by art. Direct, constant, and unrestrained communication with air, perpetually striking and then quitting them, is as necessary to a plant as to an animal; and that the Wardian Case is intended to render impossible. It is not indeed too much to add that so far as gardening, properly so called, is concerned, the Wardian Case has done nothing more than was effected years before it was suggested. As a convenient means of enabling plants to support existence under difficult circumstances it has value; and that is all. In short, it is to plants what *tripe de roche*, Bark-bread and Fern-root are to man—a means of prolonging life under difficult circumstances.

Nature no more causes plants to grow in half air-tight rooms than amidst rays of coloured light. In the natural world vegetation subsists in its greatest activity in the presence of white light; red light, and yellow light, and blue light are unknown; and if green light occurs, it is only in the recesses of deep forests, where little is to be found except Fungi, or Mosses and Ferns. So it is with unventilated places; they are the exception to the natural law, which declares that living things shall have access to air. The lowest orders of animals and the lowest of plants thrive indeed in such localities, for all places seem to have their allotted inhabitants; but the great world of vegetation knows of no healthy existence except where the air moves freely around it. In suffocated places we find lean and sickly races, too weak to stand alone, and struggling to reach a better atmosphere; these places are the Ward's Cases of the wilderness; natural accidents from which all things endeavour to escape.

When the external air is admitted into a glazed house containing a moist atmosphere, it, under ordinary circumstances, is much colder than that with which it mixes; the heated damp air rushes out at the upper ventilators, and the drier cold air takes its place; the latter rapidly abstracts from the plants and the earth, or the vessels in which they grow, a part of their moisture, and thus gives a sudden shock to their

constitution, which cannot fail to be injurious. This abstraction of moisture is in proportion to the rapidity of the motion of the air. But it is not merely dryness that is thus produced, or such a lowering of temperature as the thermometer suspended in the interior of the house may indicate; the rapid evaporation that takes place upon the admission of dry air produces a degree of cold upon the surface of leaves, and of the porous earthen pots in which plants grow, of which our instruments give no indication. To counteract these mischievous effects many contrivances have been proposed, in order to insure the introduction of fresh air warm and loaded with moisture, such as compelling the fresh air to enter a house after passing through pipes moderately heated, or over hot-water pipes surrounded by a damp atmosphere, and so on, the advantages of which, of course, depend upon the objects to be attained.

If ventilation is merely employed for the purpose of purifying the air, as is often the case in hothouses and in dung pits, it should be effected by the introduction of fresh air damp and heated. If it is only for the purpose of lowering the temperature, as in greenhouses, or in the midst of summer, the external air may be admitted without any precautions.

But it is very commonly required in the winter, for the purpose of drying the air in houses kept at that season at a low temperature; such, for instance, as those built for the protection of Heaths, and many other Cape and New Holland plants: in these cases it should be brought into the house as near the temperature of the house as possible, but on no account loaded with moisture. One of the principal reasons for drying the air of such houses is, to prevent the growth of parasitical fungi, which, in the form of mouldiness, constitute what gardeners technically call "damp." These productions flourish in damp air at a low temperature, but will not exist either in dry cold air or in hot damp air. If the air of cool greenhouses is allowed to become damp, the fungi immediately spring up on the surface of any decayed leaves, or other matter which may be present, when they spread rapidly to the young and tender parts of living plants; and when this happens they

consume the juices, choke the respiratory organs, and speedily destroy the object they attack.

How to ventilate houses without producing results even more injurious than the absence of free air, is a horticultural problem by no means solved. It is necessary—1, that the air should be as warm as that of the house; it is necessary—2, that the gardener should have the means of rendering the ventilation dry or damp at pleasure; it is necessary—3, that the method should be simple and economical. It was this which led to what is called Polmaise heating, which excited so much discussion in the pages of the *Gardeners' Chronicle* some years since; and there is little doubt that when it was skilfully applied Polmaise answered the three preceding conditions. But mechanical and other difficulties having led to the abandoning that method, it seems to be desirable to point out some of the other plans which have been found to succeed more or less completely.

In the invaluable collection of scientific papers, by Mr. Andrew Knight, collected into a volume, after his death, we find, p. 224, an account of a curvilinear Vinery, in which he attributes the inferior quality of Queen Pines grown in it to "the want of efficient ventilation;" and he proceeds to state how he remedied the evil by an improved mode of ventilation. In this house he had acquired the power of almost wholly preventing any change of air whatever; and he exercised that power too extensively, after the fruit was shown, and particularly after a part of it had nearly acquired maturity. This led him to adopt a mode of ventilation, from which he expected to derive all the advantages of change of air, without materially lowering the temperature of the house; and the success of it greatly exceeded his expectations. He first formed certain cylindrical passages of nearly two inches diameter through the front wall. Through these, which were placed eighteen inches distant from each other, along the whole front wall of the house, the air, whenever the weather was warm, was suffered to enter freely, and its entrance at other times was more or less obstructed in proportion to its coldness; but it was never wholly excluded, except during the nights in very severe weather. The passages through the front wall were placed at just such a distance from the ground as would occasion them to direct the air, which entered, either into contact with, or to pass closely over, the heated covers of the flue. It consequently became heated, and was impelled amongst the Pine-apple plants, which stood in rows behind each other, each row of plants being so far elevated above that before as to keep every plant at nearly an equal distance from the glass roof. A thermometer was so placed as to be equally distant from each end of the house, and he observed that the temperature of that part of the house in which the thermometer stood was raised between 2° and 3°, when

the external air was at 40°. This effect was produced by the heated air being impelled into the body of the house amongst the plants, instead of being permitted to rise, as it had previously done, and to come instantly into contact with the roof: by suspending light bodies amongst the plants, he ascertained that the previously confined air was thus constantly kept in a state of rapid motion. The air was suffered to escape through passages of four inches wide and two inches and a half high, just below the junction of the roof and back wall, which passages were placed at the same equal distances as those in the front wall, and, like those, were opened or closed as circumstances required. The trouble of opening or closing such passages, after substances of proper form were prepared and suspended for the purpose, was much less than that of moving the lights of any house of ordinary construction; and the effect of the kind of ventilation obtained upon the growth of his plants and fruit, was everything he wished it to be. (For the plan referred to, see *Physiological Papers*, t. 7.)

Another method, employed by Mr. Knight, was the following:—By passing pipes, open at each end, through the heating materials of a hotbed, one end being in the interior of the frame, and the other exposed to the open air, he succeeded in constantly renewing the atmosphere of the frame, and in keeping the leaves in motion, with, as he tells us, the happiest effect.

Mr. Williams, of Pitmaston, pursued another course. He kept the *south* end of his Melon-frame open to the outward air night and day, except that it was covered over with a screen of "fly-wire" painted black, and continued in the inclination of the roof. This screen received the rays of the sun from 10 A.M. to 3 P.M., all summer long; it became heated to 80° or 100°, and consequently heated the air that passed between its interstices. By raising the sashes at the back, a very powerful current of air was established; the thermometer ranged from 80° to 90° below the leaves in a sunny day, and in short the "atmosphere was as hot as is experienced in the southern parts of Italy, with almost as much ventilation as if growing in the open air."—See *Journal of Horticultural Society*, vol i., page 43. The plan of Mr. Williams might be modified by such a contrivance as is shown in the annexed section. Let A B represent a section of a front wall, or wooden frame; C, a hole; D E F, a screen of zinc or iron, painted black, nailed to it in front. It is obvious that when the sun shines on the black plate, D E, it will rapidly heat, and communicate its temperature to the air below it; the latter would immediately pass through C, and with a force proportioned to the elevation of its temperature.

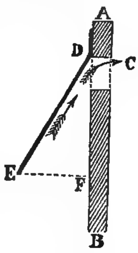


Fig. XXXII.

At Drayton Manor, the late Sir Robert Peel, with the advice, we

believe, of the celebrated George Stephenson, effected thus the ventilation of a vinery heated by hot-water. Underground drains were sunk, 3 feet deep, at right angles to the front wall, and extending from its inside to a walk about 12 feet distant from the house, and parallel with it. At each end of the drains was a perpendicular shaft; that in the inside opened immediately behind and below the hot-water pipes, and was never closed; that in the open air was closed by a moveable square plug. So long as the plug remained in its place no ventilation took place. As soon as the plug was removed, the denser external air pressed down into the shaft, and, rushing through the drain, delivered itself among the hot-water pipes, expanding rapidly in the house, and dispersing itself among the plants. The drains being always damp, on account of their depth in the moist heavy clay of Drayton Manor, the air which passed through them was always charged with as much moisture as was required. When the author saw this apparatus at work, some years since, its action was all that could be desired; and it would appear, from the following communication, made to the *Gardeners' Chronicle*, of January 28, 1854, that the merit of the plan is recognised in the neighbourhood:—"I beg to add my testimony to the advantages of underground drains for admitting air constantly to plants, especially in such weather as we have lately had, when other means of aëration must have been but limited. The plan adopted here is different from that at Drayton Manor; one large pipe is laid 3 feet deep, beginning at 90 feet from the front flues; it is carried to within 15 feet of the intended openings in the house, where three small pipes are cemented with their ends inside the larger one, one giving air in the middle of the house, the two others at equal distances on either side. It was inconvenient to bring the drain in front of the house, consequently it begins at the back, and is carried under the floor of the potting-shed and the house itself to the front flues. Besides the advantage of furnishing air at all times, the drains materially assist in keeping out frost; taking, for instance, the morning of January 3, when the thermometer was at 4°, I firmly believe that the plants would have been frozen, had it not been for the air admitted at the temperature of the earth three feet deep. I should prefer the plan employed at Drayton Manor, where the drains are in front, and each drain entire throughout. The late Mr. Milne (once gardener at Drayton) told me that the drains exceeded his most sanguine expectations, as indeed the health of his plants abundantly testified. I should mention that the heating apparatus in the house above alluded to is very small—quite insufficient for such extreme cold as that on the night of January 2. On stopping the drains on cold nights, the temperature of the house has been lower than on similar nights when the drains have been open, the external temperature in both cases being the same.—*T. Dowell, Amington Hall.*"

CHAPTER V.

OF SEED-SOWING.

When a seed is committed to the earth, it undergoes certain chemical changes before it can develope new parts and grow. These changes are brought about by heat and water, assisted by the absence of light. In many seeds the vital principle is so strong, that to scatter them upon the soil, and to cover them slightly with earth, is sufficient to insure their speedy germination; but in others the power of growth will only manifest itself under more favourable conditions: it is, therefore, necessary to consider well upon what the circumstances most suitable to germination depend.

Moisture is necessary, but not an unlimited quantity. If a seed is thrown into water and exposed to a proper temperature, the act of germination will take place: but, unless the plant is an aquatic, it will speedily perish; no doubt because its powers of respiration are impeded, and it is unable to decompose the water it absorbs, which collects in its cavities and becomes putrid. There must, therefore, be some amount of water, which to the dormant as well as the vegetating plant is naturally more suitable than any other; and experience shows that quantity to be just so much as the particles of earth can retain around and among them by the mere force of attraction. To this is to be ascribed the advantage derived from those mixtures of peat, loam, and sand, which gardeners prefer for their seedlings; the peat and sand together keep asunder the particles of loam which would otherwise adhere and prevent the percolation of water; the loam retains moisture

with force enough to prevent its passing off too quickly through the wide interstices of sand and peat.

If, during the delicate action of germination, the changes that the seed undergoes take place without interruption, the young plant makes its appearance in a healthy state; but, if by irregular variations of heat, light, and moisture, the progress of germination is sometimes accelerated and sometimes stopped, the unstable forces upon which vitality depends may become so much deranged as to be no longer able to act, and the seed will die. It is for the purpose of securing uniformity in these respects, that we employ, in delicate cases, the steady heat of a gentle hot-bed, shaded; and, in other cases, the assistance of a coating of earth scattered over the seed.

Under what depth of earth seed should be buried must always be judged of by the experience of the gardener: but it should be obvious that minute seeds, whose powers of growth must be feeble in proportion to their size, will bear only a very slight covering; while others, of a larger size and more vigour, will be capable, when their vital powers are once put in action, of upheaving considerable weights of soil. As, however, the extent of this power is usually uncertain, the judicious gardener will take care to employ, for a covering, no more earth than is really necessary to preserve around his seeds the requisite degree of darkness and moisture. An erroneous opinion is not uncommonly entertained, that seeds must be "well" buried in order that the young plants, when produced, may have "sufficient hold of the ground." But a seed, when it begins to grow, plunges its roots downwards and throws its stem upwards from a common point, which is the seed itself; and, consequently, all the space that intervenes between the surface of the soil and the seed is occupied by the base of the stem, and not by roots. This is well illustrated by the germination of such seeds as those of the Araucaria, which always grow best when merely laid on the surface of the soil with a little earth raised round their edges.

The finest Oaks spring from acorns dropped in the forest and covered by a few leaves. The Sycamore, the Ash, the

Beech, the Horse Chesnut will all sow themselves wherever their seeds can stick to the ground until a coverlet of leaves is moistened by an April shower and warmed by an April sun. Neither have such seeds any difficulty in steadying themselves by their roots; a fang is driven by vital impulse into the earth, as in the Araucaria, and it is to that, and not to the buried

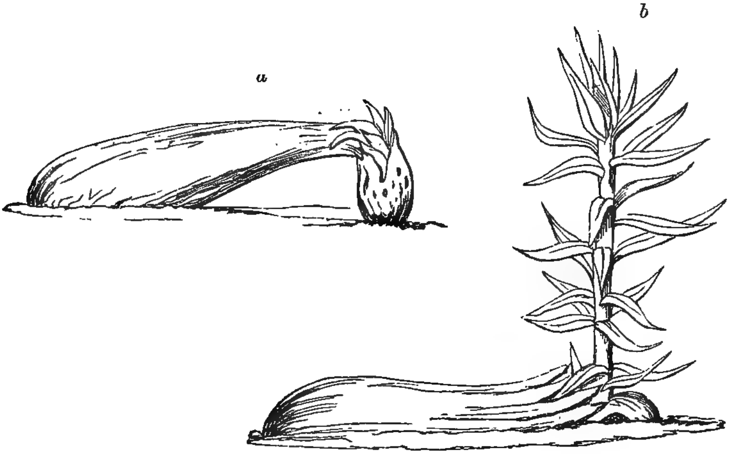


Fig. XXXIII.—Germination of Araucaria imbricata; *a*, the seed after it has inserted its radicle in the soil, the stem leaves just appearing; *b*, the same seed at a later period firmly fixed in the ground by its root.

neck of the stem, that the seedling trusts for support and nourishment.

It is not a little remarkable that not only do seeds germinate unwillingly if buried too deep, but that although they may grow they cannot, even if forest trees, develope with vigour for many years. It is for the purpose of placing seeds in the most favourable condition as regards air, light, and moisture, that when very small they are merely scattered upon the surface of the soil, and covered with a coating of straw or moss, which may be removed when the young seedlings are found to have established themselves. Inverting a garden pot over seeds in the open ground is practised for the same purpose. In other cases very minute seeds are mixed with sand before they are sown.

The latter practice is not, however, merely for the sake of covering the seed with the smallest possible quantity of soil, but has for its object the separation of seeds to such a distance, that when they germinate they may not choke up each other. If seedlings, like other plants, are placed so near together that they either exhaust the soil of its organizable matter, or overshadow each other so as to hinder the requisite quantity of light, some will die in order that the remainder may live; and this, in the case of rare seeds, should, of course, be guarded against very carefully.

> "The injuriousness of covering seed with too much earth arises less from the superincumbent pressure of the soil, than from the exclusion of atmospheric air, which is quite indispensable to germination. The seed of the common Flax comes up at different periods, according as it is planted in one, two, or three inches depth of soil; if it be sown four inches below the surface it will not come up at all. Not that air does not penetrate to this depth in the soil, but the quantity of air will very much depend on the looser or denser character of the soil. Thouin, in his *Cours d' Agriculture*, remarks that small seeds should be covered only a line deep with earth, and this spread over very loosely; seeds of the size of Peas and Beans, about three-quarters of an inch deep, and the bulky seeds of our fruit-trees, such as the Apricot, Nuts, Peaches, Almonds, with from two to three inches of soil."—*German Translation.*

With regard to the temperature to which a seed should be subjected, in order to secure its germination, this, undoubtedly, varies with different species, and depends upon their peculiar habits, and the temperature of the climate of which they are native. So far as general rules can be given upon such a subject, it may be stated that the temperature of the earth most favourable for germination is 50° to 55° for the seeds of cold countries, 60° to 65° for those of "greenhouse plants," and 70° to 80° for those of the torrid zone. We are assured by Mr. Cowan, that although the Cocoa-nut is cultivated in the mountainous parts of Jamaica; where the atmospheric temperature varies from 60° to 90°, it only assumes the characteristic grandeur of Palms, and can only be propagated with certainty, by the seaside, where the heat of the soil exceeds 120°. And it may be laid down as a rule, in sowing tropical

seeds, that, how well soever a plant may grow at the minimum temperature of its native locality, the maximum temperature of that spot ought to be maintained while the seeds are vegetating.

We have no exact experiments upon this subject, except in a few cases recorded by Messrs. Edwards and Colin, by whom there is a very valuable set of observations upon the temperatures borne by certain agricultural seeds (*Annales des Sciences*, 2nd series, vol. v. p. 5), the result of which may be thus stated :—

At 44·6°, Wheat, Barley, and Rye could germinate.
95°, *in water*, for three days, $\frac{4}{5}$ of the Wheat and Rye, and all the Barley, were killed.
104°, *in sand and earth*, the same seeds sustained the temperature for a considerable time, without inconvenience.
113°, under the same circumstances, most of them perished.
122°, ditto ditto all perished.

But it was found that, for short periods of time, a much higher temperature could be borne.

At 143·6, *in vapour*, Wheat, Barley, Kidneybeans, and Flax retained their vitality for a quarter of an hour; but in $27\frac{1}{2}$ minutes, the three last died at a temperature of 125·6°.
167°, *in vapour*, they all perished.
167°, *in dry air*, they sustained no injury.

It will be presently seen that some seeds will bear a much higher temperature.

"In order to render this important subject yet more clear, we subjoin a report on the labours of Edwards and Colin, derived from the pages of Froriep's *Zeitschrift*. Messrs. Edwards and Colin read an article upon this subject before the Academy of Sciences on the 18th of April, 1837, which constitutes the third part of their *Researches upon Agricultural Physiology*. Their experiments led to the following results:—

1. "In free moist air, yet considerably removed from the point of saturation, seeds did not germinate.

2. "Germination took place among Cereal plants, Summer Wheat, Winter Wheat, Barley, Oats, Rye, when placed in an atmosphere fully saturated with moisture.

3. "When placed under water they required eight times as long a period before they germinated.

4. "If the number of seeds or grains be increased, and twenty-five be employed instead of five, and brought into an atmosphere saturated with moisture, without placing the experiment under a larger bell than in the last instances, germination does not take place.

5. "The same is also the case if the original number, for instance, five grains are employed, and covered with a bell much larger, in which case germination is very much retarded, if not prevented.

6. "The circumstances which produce this retardation or hinderance of germination, depend on the influence of temperature upon the moisture of the air.

7. "If the temperature is low, and undergoes little or no change, germination will take place as soon under a small bell as under a large one.

8. "If the temperature is higher, moderate, and changeable, the germination will be retarded under a large bell.

9. "This occurs when during the daily change the temperature increases, and the air has a tendency to depart from a state of perfect saturation, and if the space is great, the diffused vapour is in part absorbed by the seed, and the air never reaches the point of saturation.

10. "These effects probably do not proceed from the fact that the seed had not absorbed enough vapour; in a low constant temperature seeds absorb less water than in a higher, and in the first case germination takes place, and in the last it is retarded or entirely prevented.

11. "These remarkable facts are produced by the air not being sufficiently saturated with vapour to allow of the necessary application of moisture to the external membrane of the seed.

12. "In germination, two principal conditions with regard to the vapour are required to take place; first, that the seed absorbs enough vapour for the function of nutrition; and second, that the external air be saturated with sufficient vapour to soften sufficiently the testa of the seed.

13. "Through the simultaneous action of water and vapour, germination constantly takes place, and earlier where the air is saturated with moisture.

14. "With regard to the application of these principles to seeds sown in different kinds of soil, the authors found that germination took place by the agency of vapour when seeds were placed in sand and clay, but in both cases the process was longer, especially in the clay, which absorbed the vapour slowly, and imparted it slowly to the seeds."—*German Translation.*

The foregoing observations apply to seeds in a perfect state of health; when they have become sickly or feeble, from age or other causes, some precautions become necessary, to which,

under other circumstances, no attention requires to be paid. When the vital energies of a seed are diminished, it does not lose its power of absorbing water, but it is less capable of decomposing it. The consequence of this is that the free water introduced into the system collects in the cavities of the seed, and produces putrefaction; the sign of which is the rotting of seeds in the ground. The remedy for this is to present water to the seed in such small quantities at a time, and so gradually, that no more is absorbed than the languid powers of the seed can assimilate; and to increase the quantity only as the dormant powers of vegetation are aroused. One of the best means of doing this is to sow seeds in warm soil tolerably dry; to trust for some time to the moisture that exists in such earth and the atmosphere for the supply required for germination; and only to administer water when the signs of germination have become visible; even then the supply should be extremely small. If this is attended to, carbonic acid is very slowly formed and liberated; the chemical quality of the contents of the seed is thus insensibly altered, each act of respiration may be said to invigorate it, and by degrees it will be brought to a condition favourable to the assimilation of food in larger quantities. Mr. Knight used to say that these effects were produced in no way so well as by enclosing seeds between two pieces of loamy turf, cut smooth, and applied to each other by the underground sides; such a method is, however, scarcely applicable to any except seeds of considerable size.

"It will happen at times that small seeds, such as Cabbage seed, Broccoli, Brussels Sprouts, &c., do not come away after they are sown, during dry and warm weather. Last spring, some of my crops failed in the first sowing. About a month after the regular time for sowing these seeds, a few drills were made in moist peat, and in the drills was put some guano, to cover which peat-mould was also used. The seeds were afterwards sown, being chiefly Broccoli, Cabbages and Iceland Greens. After they were sown and covered up, the heat still continued; the surface of the peat became as dry as tinder, and would have burned if fire had been applied to it. However, the seed that was sown vegetated freely, the plants grew rapidly, and were as fit for planting out at the proper time as the few that remained of those that had been sown a month before. Another great advantage attended those that

were sown in the peat: when they required to be lifted, the roots brought a ball of peat along with them, which I think was very beneficial to the plants, in keeping the roots moist after they were planted in the ground where they were to remain. It may not be necessary to sow at all times in such a soil; but I believe that a garden would be none the worse in having a few square yards of well-broken peat for sowing some kinds of seeds upon, as occasion might require."—*Peter Mackenzie, in the Gardeners' Chronicle.*

In all cases it is useful to sow seeds on fibrous matter of some kind when they have to be transplanted. Mr. Knight used chopped hay; others use broken horse-droppings, the object in every case being to give the seedlings something in which their roots may be entangled at the time of transplantation, so as to remove without injury.

Other expedients have occasionally been had recourse to successfully. Where seeds are enclosed in a very hard dry shell, it is usually necessary to file it thin, so as to permit the embryo to burst through its integuments when it has begun to swell. Under natural circumstances, indeed, no such operation is practised: but it is to be remembered that such seeds will have fallen to the ground as soon as ripe, and before their shell acquired the bony hardness that we find after they have become dry.

Sometimes it has been found useful to immerse seeds in tepid water until signs of germination manifest themselves, and then to transfer them to earth; but this process cannot be applied with advantage to seeds in an unhealthy state; and it is only of use to healthy seeds, by accelerating the time of growth, a practice which may, in out-door crops, be desirable when applied to seeds which, like the Beet, the Carrot, or the Parsnip, will, in dry seasons, lie so long in the ground without germinating that they become a prey to birds or other animals.

During the spring months, seed sowing is very apt to get into arrear. When such is the case, a fortnight may be recovered by having recourse to the steeping process, and it is always a safe plan during the prevalence of drought. There is sometimes moisture in the ground sufficient to induce the first stage of germination, yet by the time that is accomplished, and before the tender radicle has extended beyond the reach of accident, drought has overtaken it. But in all cases if a seed is on the eve of germination, previous to its insertion in the soil, and if the soil is fresh dug, the young plant will in general establish itself in

safety. A method employed by practical men is to steep seed in water of about 80° for about six hours or more, according to the character of the seed, and to place the vessel where it will maintain that temperature; then to strain the water away, and to remove the vessel to a more moderate temperature, say 65°, until the first signs of sprouting, when the seed-bed should be instantly prepared; the vessel, after pouring the water off, should be covered with a cloth to prevent the surface seeds from drying up; it is also necessary to turn the seeds once or twice, in doing which care must be taken that the young radicle, if it has chipped the shell, be not broken off.

Of late years the singular practice has been introduced of *boiling* seeds to promote germination. This was, I believe, first recommended by Mr. Bowie, who stated, in the *Gardener's Magazine*, vol. viii. p. 5. (1832), that "he found the seeds of nearly all leguminous plants germinate more readily by having water heated to 200°, or even to the boiling point of Fahrenheit's scale, poured over them, leaving them to steep and the water to cool for twenty-four hours." Subsequently, the practice has been adopted by other persons with perfect success; and, some years ago, seedlings of Acacia lophantha were exhibited before the Horticultural Society by the late Mr. Thomas Cary Palmer, which had sprung from seeds boiled for as much as five minutes. I am also acquainted with other cases, one of the more remarkable of which was the germination of the seeds of the Raspberry, picked from a jar of jam, and which must therefore have been exposed to the temperature of 230°, the boiling point of syrup. It is difficult to understand in what way so violent an action can be beneficial to anything possessing vitality; the fact, however, is certain. As such instances of success are confined to seeds with hard shells, it is possible that the heated fluid may act in part mechanically by cracking the shell, in part as a solvent of the matters enclosed in the seed, and in part as a stimulant.

Some years since Mr. Lymburn, nurseryman at Kilmarnock, called attention to the effect produced upon germinating seeds by alkaline substances. He stated that experiments narrated in Brewster's *Journal of Science*, having shown that the negative or alkaline pole of a galvanic battery caused seeds to germinate in much less time than the positive or acid pole, he was induced

to observe the effects on seeds of acetic, nitric, and sulphuric acids, and also of water rendered alkaline by potash and ammonia. "In the alkaline the seeds vegetated in thirty hours, and were well developed in forty; while in the acetic and sulphuric they took seven days; and, even after a month, they had not begun to grow in the acetic." This experiment led to others upon lime; "a very easily procured alkali, and which he inferred to be more efficient than any other from the well known affinity of quick or newly slacked lime for carbonic acid. Lime, as taken from the quarry, consists of carbonate of lime, or lime united to carbonic acid; but, in the act of burning, the carbonic acid is driven off; and hence the great affinity of newly slacked lime for carbonic acid. He depended, therefore, upon this affinity to extract the carbon from the starch, assisted by moisture;" (*Gard. Mag.*, xiv. 74) and he reported that the results were exceedingly striking. Old Spruce Fir seed, which would scarcely germinate at two years old, produced a fine healthy crop when three years old, having been first damped and then mixed with newly slacked lime; and, under the same treatment, an average crop of healthy plants was obtained when the seed was four years old. The manner in which the original experiments upon acids and alkalies were conducted is not explained; it is to be presumed that the water employed was only *acidulated* with the acids spoken of. It is, however, certain that whatever effect may be practically experienced when particular solutions are employed it has no relation to electrical action. Mr. Edward Solly proved experimentally in the garden of the Horticultural Society that electricity has no discoverable influence upon vegetation either in its active growth or during the period of germination. (See *Journal of Hort. Soc.* vol. i., p. 81, and ii., p. 45.)

The last method of promoting germination, to which it is necessary to advert, is the mixing seeds with agents that have the power of liberating oxygen. It has been shown that a seed cannot germinate until the carbon with which it is loaded is to a considerable extent removed; the removal of this principle is effected by converting it into carbonic acid, for which purpose a large supply of oxygen is required. Under ordinary circum-

stances, the oxygen is furnished by the decomposition of water by the vital forces of the seed; but when those forces are languid, it has been proposed to supply oxygen by some other means. Humboldt employed a dilute solution of chlorine, which has a powerful tendency to decompose water, and set oxygen at liberty, and, it is said, with great success. Oxalic acid has also been used for the same purpose. Mr. Otto, of Berlin, states that he employs oxalic acid to make old seeds germinate. The seeds are put into a bottle filled with oxalic acid, and remain there till the germination is observable, which generally takes place in from twenty-four to forty-eight hours, when the seeds are taken out, and sown in the usual manner. Another way is to wet a woollen cloth with oxalic acid, on which the seeds are put, and it is then folded up and kept in a stove; by this method small and hard seeds will germinate equally as well as in the bottle. Also very small seeds are sown in pots and placed in a hotbed; and oxalic acid, much diluted, is applied twice or thrice a day till they begin to grow. Particular care must be taken to remove the seeds out of the acid as soon as the least vegetation is observable. Mr. Otto found that by this means seeds which were from twenty to forty years old grew, while the same sort, sown in the usual manner, did not grow at all (*Gard. Mag.*, viii. 196): and it is asserted by Dr. Hamilton (*Ib.*, x. 368, 453,) and others, that they have found decided advantages from the employment of this substance. Theoretically it would seem that the effects described ought to be produced, but general experience does not confirm them; and it may be conceived that the rapid abstraction of carbon, by the presence of an unnaturally large quantity of oxygen, may produce effects as injurious to the health of the seed, as its too slow destruction in consequence of the languor of the vital principle.

It is an old assertion, revived within the last few years, that certain agents have a powerful action not only upon the germinating seed, but upon plants in their after growth, and that marvellous crops have been obtained by mere SEED-STEEPING, in certain solutions, without other aid. A German, of the name of Bickes, has more especially made himself conspicuous for the enthusiasm with which he has propagated this opinion. That he laboured under some delusion, is, however,

certain; for no such results as those he speaks of can be obtained. (*See Journal of the Hort. Soc.*, vol. ii. p. 35.) The subject has been treated with great care by Professor Edward Solly, whose experiments are recorded in the *Transactions of the Hort. Soc.*, *2nd series*, vol. iii. p. 197. Not only did he fail to discover any practical advantage in steeping seeds in chemical solutions, but upon the whole his results showed it to be injurious; and in no one instance did it appear that the effect of the steeping went beyond the period of germination. The trial of Bickes' method equally failed in the *Jardin des Plantes*, as we learn from the *Revue Horticole.*

The length of time that some seeds will lie in the ground, under circumstances favourable to germination, without growing, is very remarkable, and inexplicable upon any known principle. If the Hawthorn be sown immediately after the seeds are ripe, a part will appear as plants the next spring; a larger number the second year; and stragglers, sometimes in considerable numbers, even in the third and fourth seasons. Seeds of the genera Ribes, Berberis, and Pæonia have a similar habit. M. Savi is related by De Candolle to have had, for more than ten years, a crop of Tobacco from one original sowing; the young plants having been destroyed yearly, without being allowed to form their seed. This matter does not, perhaps, concern the theory of horticulture, for theory is incapable of explaining it; but it is a fact that it is useful to know, because it may prevent still living seeds from being thrown away, under the idea that, as they did not grow the first year, they will never grow at all.

Mr. Hunt believes that coloured light exercises a peculiar influence upon germination; that yellow light prevents it, and red light impedes it, while blue light accelerates it in a remarkable degree. But when seeds have been made to germinate beneath red, yellow, and blue plates of glass, no other result has been practically obtained than what may be referred to the action of bright light on the one hand, and shade on the other. If under blue glass seeds germinate more quickly than under red or yellow, it seems to be because they are much more shaded. At all events Mr. Hunt's ingenious inquiries into the effect of coloured light on plants seem to have no practical bearing.

CHAPTER VI.

OF SEED-SAVING.

THE maturation of the seed, being a vital action indispensable to the perpetuation of a species, is, in wild plants, guarded from interruption by so many wise precautions, that no artificial assistance is required in the process; but in gardens, where plants are often enfeebled by domestication, or exposed to conditions very different from those to which they are subject in their natural state, the seed often refuses to ripen, or even to commence the formation of an embryo. In such cases, the skill of gardeners must aid the workings of nature, and art has to effect that which the failing powers of a plant are unable to bring about of themselves.

Sterility is a common malady of cultivated plants; the finer varieties of fruit, and all double and highly cultivated flowers, being more frequently barren than fertile. This arises from several different causes.

The most common cause of sterility is an unnatural development of some organ in the vicinity of the seed, which attracts to itself the organizable matter that would otherwise be applicable to the support of the seed. Of this the Pear, the Pine-apple, and the Plantain are illustrative instances. The nutrition which is intended for the seed is applied to the enlargement of the fleshy part of such fruits, and the seeds are starved. The more delicate varieties of Pear, such as the Gansel's Bergamot and the Chaumontelle, have rarely any seeds; of Pine-apple, none, except the Enville now and then, have seeds, and that variety, though a large one, is of little

value for its delicacy, and probably approaches nearly to the wild state of the plant; of Plantains few, except the wild and crabbed sorts, are seedful. The remedy for this appears to be, the withholding from such plants all the sources from which their succulence can be encouraged. If, in consequence of any predisposition to form succulent tissue (on which the excellence of fruit much depends), the organizable matter of the plant be once diverted from feeding the seed to those parts in which the succulence exists, it will continue, by the action of endosmose, to be attracted thither more powerfully than to any other part, and the effect of this will be the abortion of the seed: but a scanty supply of food, an unhealthy condition of the plant itself, or withholding the usual quantity of water, will all check the tendency to luxuriance, and therefore will favour the developement of the seed, whose feeble attracting force is, in that case, not so likely to be overcome by the accumulation of attracting power in the neighbouring parts. Thus we see that Pine-apples are more frequently seedful under bad cultivation, than in highly kept and skilfully managed pineries. Abstraction of branches, in the neighbourhood of fruit, has also been occasionally found favourable to the formation of seed; evidently because the food that would have been conveyed into the branches, having no outlet, is forced into the fruit, and thus reaches the seed.

Another cause of sterility is the deficiency of pollen in the anthers of a given plant, as in vegetable mules, which usually partake of the spermatic debility so well known in similar cases in the animal kingdom. It has often been found that sterility of this kind is cured by the application, to the seedless plant, of the vigorous pollen of another less debilitated variety.

In some plants, such as Pelargoniums, when cultivated, the anthers shed their pollen before the stigma is ready to receive its influence, and thus sterility results. All such cases are provided for, by employing the pollen of another flower. (See Sweet in the *Gardener's Magazine*, vii. 206.)

An unfavourable state of the atmosphere obstructs the action of pollen, and thus produces sterility. Pollen will not

produce its impregnating tubes in too low a temperature, or when the air is charged with moisture; neither, in the absence of wind or insects, have some plants the power of conveying the pollen to the stigma, their anthers having no special irritability, and only opening for the discharge of the pollen, not ejecting it with force, unless the filaments are irritable enough to knock the anther violently against the pistil; or, unless the stigmatic apparatus possesses special irritability, as is the case with certain Orchids. If we watch the Hazel, or any of the Coniferous order, in which the enormous quantity of pollen employed to secure the impregnation of the seed renders it easy to see what happens, it will be found that no pollen is scattered in damp cold weather; but, in a sunny, warm, dry morning, the atmosphere surrounding such plants is, in the impregnating season, filled with grains of pollen discharged by the anthers. In wet springs the crops of fruit fail, because the anthers are not sufficiently dried to shrivel and discharge their contents, which remain locked up in the anther cells till the power of impregnation is lost; or perhaps because, as a critic has suggested, the wet operates injuriously upon the very constitution of the pollen, and of the stigmatic surface. In vineries and forcing-houses generally, into which no air is admitted to disturb the foliage, nor any artificial means employed for the same end, and when the season is too early for the presence of bees, flies, and other insects, the grapes will not set: and in the frames of Melons and Cucumbers, from which insects are excluded, no seed is formed unless the pollen is conveyed by hand, from those flowers in which it is formed, to others in which the young fruit alone is generated. In all cases of this kind, the remedy for sterility, where plants exist in an artificial condition, is evidently to set, or fertilise them by hand; but, when they occur in the orchard or the flower-garden, science suggests no assistance. It is by hand-setting alone that in hot-houses, and in tropical Asia, the Vanilla, a native of tropical America, can be made to bear fruit; because, as is believed, the insects which haunt the Vanilla flowers in America, and set them, are unknown in Europe and Asia.

It sometimes happens that particular parts of plants, distant from the fruit, are so constructed as to attract to themselves the food intended for the fruit, and thus to prevent the formation of seed. For example:—The early varieties of Potato do not readily produce seed, owing to the abstraction by their tubers of the nutritive matter required for the support of the seed. Mr. Knight found that by destroying the tubers in part, as they formed, seeds were readily procured from such varieties.

But perhaps the most frequent cause of sterility is the monstrous condition of the flowers of many cultivated plants. It was explained in Book I. that the floral organs of plants are nothing more than leaves, so modified as to be capable of performing special acts, for particular purposes; but they are not capable of performing those acts any longer than they retain their modified condition: and therefore the stamens cannot secrete pollen, when, by accidental circumstances, they are changed into leaves, as happens in double flowers; in such cases, there is nothing to fertilise the stigma, and, of course, no seed is produced. Or the carpels themselves may be converted into leaves, and have lost their seed-bearing property. Double flowers in the latter case cannot possibly bear seed; but in the condition first mentioned they may, and often do. To bring this about, the cultivator plants in the vicinity of his sterile flowers others of the same species, in which a part at least of the stamens are perfect, and they furnish a sufficiency of pollen for the impregnation of the other flowers in which there are no stamens.

In some cases, principally in those of Composite flowers, the seed is formed and advanced towards perfection, and then decays; this is owing to the flower heads of such plants being composed, in a great measure, of soft scales, absorbent and retentive of moisture, to which, in their own country, they are not exposed in the fruiting season, but by which they are affected under the hands of the cultivator. When the heads of such flowers are soaked with moisture, which they cannot get rid of, the scales rot, decay spreads to all the other parts, and thus the production of seed is prevented. The Chinese

Chrysanthemum is a familiar instance of this. Such plants seed readily if the flower heads are kept warm and dry; and it is thus that the sterile Chrysanthemum has been made seedful; that is to say, by growing it in a dry warm winter border, protected from showers by a roof of glass; or by using some similar means of guarding it; or by rearing it in a warm dry climate.

When seeds are freely produced, it is not altogether a subject of indifference in what way they are saved, if it is desired that their progeny should be the most perfect that can be obtained. Weak seeds produce weak plants, and therefore recourse should be had, in all delicate cases, to artificial means for gaining seminal vigour. In general, the cultivator trusts to his eye for separating the plumpest and most completely formed seeds; or to floating them in water, selecting only the heavy grains that sink, and rejecting all those which are buoyant enough to float. But the energy of the vital principle in a seed may be, undoubtedly, increased by abstracting neighbouring fruits, by improving the general health of the parent plant, by a full exposure of it to light, and by prolonging the period of maturation as much as is consistent with the health of the fruit.

It is a general rule that seedlings take after their parents, an unhealthy mother producing a diseased offspring, and a vigorous parent yielding a healthy progeny in all their minute gradations and modifications; and this is so true, that, as florists very well know, semi-double Ranunculuses, Anemones, and similar flowers, will rarely yield double varieties, while the seed of the latter as unfrequently give birth to semi-double degenerations.

Independently of these things, it is indispensable that the seed of a plant, when saved, should be perfectly ripe, if it is intended to be laid by for future sowing. The effect of ripening is to load the seed with carbon in the form of starch, or some other substance of a similar kind, and to deprive it of water, conditions necessary for its preservation: but, if a seed is gathered before being ripe, these conditions are not secured; and, in proportion to the deficiency of the requisite elements

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which maintain vitality, and superabundance of water, is the seed liable to perish.

The complete maturation of the seed is, however, a disadvantage, when it has to be sown immediately after being gathered; for the embryo is formed, and capable of germinating, long before the period of greatest maturity. There are two periods in the latter part of the organization of a seed which, although separated by no limits, require to be distinguished. The first is that when the embryo is completed; and the second is when nature has, in addition, furnished it with the means of maintaining its vitality for a long period. It is just as capable of growing at the expiration of the first period as of the second; it will do so immediately if committed to the ground; and we see it actually happening to Peas, Beans, Corn, and other field crops, in wet summers; but at the end of the second period, it cannot germinate till it has relieved itself of matters not required for vegetation, which, during that period, were deposited in its tissue.

If seeds are to be preserved for a length of time, a state of complete dryness is so necessary to them that it has been recommended to increase it by artificial means; not, however, by the application of heat, or by any process like that of kiln-drying, which would destroy their vitality; but by some of those chemical processes that dry the atmosphere without raising its temperature. It occurred to Mr. Livingstone, that air made dry by means of sulphuric acid might be advantageously employed for this purpose, and he says that the success of his experiments was complete. He placed the seeds to be dried in the pans of Leslie's ice machine, and carefully replaced the receiver without exhausting the air; small seeds were sufficiently dried in one or two days, and the largest seeds in less than a week. (*Hort. Trans.*, iii. 184.) Other contrivances might easily be adopted. Muriate of lime, for instance, which has the property of absorbing the moisture of the atmosphere, might, perhaps, be employed with advantage in drying the air in which seeds are placed after being gathered. But such devices have little practical value, the sun being the great power to which the gardener very properly trusts.

CHAPTER VII.

OF SEED-PACKING, AND PLANT-PACKING.

It seldom happens that seeds are sown as soon as they are ripe; it is sometimes desirable that they should be preserved for long periods of time; the power of conveying them for great distances, through various climates, is one of those upon which man most depends for the improvement of the horticultural resources of all countries; and for this purpose large sums are annually expended, both by governments and individuals. It is, therefore, an object of the first importance to ascertain what is not well understood, as it would seem, namely, the causes by which the destruction of the germinating power of seeds is effected; for it is only by doing this, that their preservation can be secured.

Seeds are probably possessed of different powers of life, some preserving their vital principle through centuries of time, while others have but an ephemeral existence under any circumstances. The reasons for this difference are unknown to us, and apparently depend upon specific vitality, over which we have no control; but the fact of great longevity in some seeds is certain, and it is highly desirable that the conditions which enable them to preserve their germinating power for long periods of time should be discovered.

It is, however, extremely difficult to reconcile with all known facts any theory which physiology may suggest. What applies to one class of cases fails to explain others. The instances already mentioned at p. 103, are sufficiently conflicting; for they include examples both of dryness and wetness, and of exclusion of air and its admission; dryness and exclusion of air

being generally regarded as the immediate causes of long protracted seminal vitality. The following instance mentioned by a correspondent of the "*Gardeners' Chronicle*, (1843, p. 862) is still more difficult of explanation. "In the progress of some improvements about my premises, we had occasion to remove an old privy, with its cesspool. After the removal of the soil from the cistern of the latter, a ladling or dipping-hole was discovered at one corner, completely filled with Gooseberry, Currant, and Grape seeds, and a few Cherry-stones; in all, about half a bushel. It was evident that these seeds had been the contributions of many summers, and that after resisting the decomposing powers of human digestion, and then of the putrid mass in which they had lain so long, they had made their way, by their superior gravity, into the hole in question, to the exclusion of all the more soluble materials. The cesspool and its superstructure were known to be at least fifty years old; and although it was occasionally cleared out, it had never been thought worth while to make the clearance so complete as to empty the hole in which this curious 'depôt' had been made. The brickwork being grubbed up, and the soil and seed thrown into a compost, little more was thought of the matter till the next year, when, and for three or four years after, seedling Gooseberries, Cherries, and Currants were found springing in great numbers all about my garden, in various parts of which the manure of this compost had been distributed." The ingenious observer from whom this fact was derived, suggested in explanation, that "although we are not warranted in supposing that any animal ovum can exist for years, much less centuries, unchanged, under the most favourable circumstances we can have any conception of, resistive of external agencies, yet, such instances as the above, and that of Elder-seed," mentioned in the *Magazine of Natural History*, for 1843, which when strewed on the ground for manure came up in abundance, although twice boiled in the process of making wine and even afterwards present during fermentation, "would incline one to believe, that in a lower order of created beings certain molecular attractions may subsist for an indefinite period conservative of the predisposition to vegetative action. This can hardly

be called life; it must be merely chemical combination, with aptitude for life."

The prevailing opinion on this subject among physiologists is, that germination can only take place when moisture, warmth, and a free communication with atmospheric air are *simultaneously* present. If so, then such cases as the preceding may be explained by the absence of one or other of the three conditions assumed to be indispensable, moisture, heat, and communication with the air.

The power of moisture exposed to the air, and in contact with inert vegetable matter, such as a torpid seed, is by degrees to produce decay, which rapidly spreads to the neighbouring parts. But, if the vitality of a seed is excited by a fitting temperature, the moisture with which it is in contact is then decomposed, the oxygen so obtained combines with the carbon of the seed, and forms carbonic acid which flies off, other changes take place, and by degrees the matters lodged in the tissue of the seed are brought into that condition which is best suited for the growth of the embryo; then, if the embryo is so situated that it cannot obtain from the surrounding medium food upon which to subsist, its germination stops, and its stable constituents having been exchanged for unstable ones, the safeguard of its vitality is removed, and it perishes. If, however, the amount of moisture in contact with a seed is very small, as in the dry earth at the bottom of a tumulus for instance, the temperature at the same time low, and the access of atmospheric air cut off, neither putrefaction nor germination is likely to occur.

When seeds are exposed to a high temperature in dryness, they will not perish, unless the temperature rises beyond any thing likely to occur under natural circumstances. Edwards and Colin found that even wheat, barley, and rye, inhabitants of temperate countries, would bear when dry 104° for a long time without injury, although they died in three days in water at 95°; and a much higher prolonged temperature may be expected to produce no ill effect upon seeds inhabiting hotter countries. There is no apparent reason why the exposure of dry seeds to the air should destroy vitality,

unless the exposure is very much prolonged; nor have we any evidence to show that it does, so long as they remain dry. The way in which the atmosphere would act injuriously upon dormant seeds is, by its oxygen abstracting their carbon; and it was formerly supposed that the carbonic acid extricated by germinating seeds was formed in this way. But the very valuable observations and experiments of Messrs. Edwards and Colin (See *Comptes rendus de l'Académie des Sciences*, vii. 922) show that carbonic acid is formed by the assistance of the oxygen obtained by the decomposition of water.

Chemists may question the sufficiency of this explanation; but, at all events, it will not be denied that the preservation of vitality in seeds depends upon preserving the stability of the chemical compounds of which they consist. This we believe to be the hinge upon which everything turns. Before a seed is quite ripe its elements are highly unstable or liable to change, and the least alteration in the conditions to which they may be exposed will cause it either to germinate or perish, as is seen in Oranges and Cucumbers, whose seeds will often germinate while hidden within the fruit that bears them. But when a seed is perfectly ripe its elements become comparatively stable or indisposed to change, and to induce germination is in proportion difficult, while those alterations which are succeeded by death are slow in taking effect.

If we apply these considerations to the plans usually employed for preserving artificially the vitality of seeds, we shall find them offer an explanation of the success that attends some methods of packing, and the failure of others.

The great object of those who have devised means of packing seeds for distant journeys has, in general, been to exclude the air, and all other considerations have been subordinate to this. Enclosure in bottles hermetically sealed, in papers thickly coated with wax, in tin boxes, and similar contrivances, have, therefore, been resorted to: but no advantage can be derived from excluding the air, and the disadvantage is very great; for the effect of excluding the air is to include whatever free moisture seeds may contain or be surrounded by; this moisture is sufficient, in high temperatures, to excite germination, which, when it cannot be continued, inevitably ends in a decay of the tissue, especially of the seed coats, which have no vitality themselves, and the embryo perishes.

What has, perhaps, tended to confirm this erroneous opinion have been the stories current about seeds enclosed in mummy-cases for thousands of years, having germinated. The newspapers abound in such tales, which are all apocryphal, if not absolutely false. Even Mr. Tupper's mummy wheat, said to be the produce of grains taken out of a mummy-case by Sir Gardner Wilkinson, (See *Gard. Chron.*, 1846, p. 757.) has been declared, by very high authority, to be a mystification of the Arab guides. It is, however, to such instances that we may ascribe the origin of wrapping seeds in wax-cloths, like the cerements of the dead, or soldering them up in metal boxes, or hermetically sealing them in glass.

Packing in charcoal has been recommended, it is difficult to say why; and experience shows what might have been anticipated, that it produces no other effect than packing in earth or other dry non-conducting material.

Clayed sugar has been employed, and, as it is said, occasionally with advantage; but I have seen no instance of success, and, on the contrary, its tendency to absorb moisture from the air till it becomes capable of fermenting, is in itself an objection to the employment of this substance.

It is obvious that any contrivance which keeps out of a packet of seeds the air of *our* atmosphere, will keep in the air of *theirs*. Now the air of our atmosphere is dry, or if occasionally damp, soon becomes dried, if seeds are exposed to it in a room in which we live. On the other hand, all seeds are necessarily damp, and they communicate their moisture to the air that surrounds them; the papers too in which they are packed are damp, as may be seen by holding such papers before a fire, when the damp will dry off in the form of vapour; and if this air which surrounds the seeds is enclosed in an air-tight vessel of any kind, it must always remain damp, because it cannot be dried by ventilation. We may therefore assume, that seeds in air-tight vessels are damp, but in situations freely communicating with the atmosphere are comparatively dry. So long as seed-packages are kept at a low temperature, this difference is of no moment; because seeds cannot germinate, or, in other words, cannot revive from their torpor, in a low temperature: but let the temperature rise and the case is altered. What seeds require in order to grow are moisture

and warmth; they cannot grow in damp without heat, nor in warmth without moisture. It is the combination of these two conditions that is absolutely requisite. When they arrive in warm latitudes, or are placed in warm situations, such as the hold of a ship, the seeds in air-tight cases, being surrounded with moisture, attempt to grow; those, on the contrary, which are in ventilated packages, not being surrounded with moisture, remain unchanged. The commencement of growth made by the seeds in air-tight cases is presently arrested, in consequence of the unfavourable circumstances under which it takes place, and the seeds not being able to return to the state in which they were before they began to germinate, speedily perish; but the seeds in ventilated packages, not having begun to grow, still remain unaltered. The irresistible conclusion from this is, that the true mode of packing seeds for long voyages is, to put them in well-ventilated packages, and not in closed-up cases. Such dryness as seeds can acquire from exposure to the air cannot hurt them, but will, on the contrary, tend to preserve their germinating powers.

Upon the whole, the only mode which is calculated to meet all the circumstances to which seeds are exposed during a voyage is, to dry them as thoroughly as possible, enclose them in coarse paper, and to pack the papers themselves very loosely in coarse canvass bags, not enclosed in boxes, but freely exposed to the air; and to insure their transmission in some dry well-ventilated place. Thus, if the seeds are originally dried incompletely, they will become further dried on their passage; if the seed paper is damp, as it almost always is, the moisture in it will fly off through the sides of the bags, and not collect around the seeds. It is true that, under such circumstances, the seeds will be exposed to great fluctuations of temperature, and to the influence of the atmosphere; but neither the one nor the other of these is likely to be productive of injury to the germinating principle. The excellence of this method I can attest from my own observation. Large quantities of seeds have been annually transmitted from India for many years, doubtless gathered with care, it is to be presumed prepared with attention to the preservation of the vital principle, and

certainly packed with all those precautions which have been erroneously supposed to be advantageous; the hopelessness of raising plants from such seeds at length became so apparent, that persons would not take the trouble to sow them when they arrived. On the other hand seeds sent from India, packed in the manner last described, exposed to all the accidents which those first mentioned can have encountered, germinate so well, that we can scarcely say that the failure has been greater than if they had been collected in the south of Europe.

It is not to be doubted that the general badness of the seeds from Brazil, from the Indian Archipelago, and from other intertropical countries, is almost always to be ascribed to the seeds having been originally insufficiently dried, and then enclosed in tightly packed boxes, whence the superfluous moisture had no means of escape.

But although experience shows that as a general rule in SEED-PACKING, the great points to observe are the drying seeds thoroughly before packing, and the preserving them in that state afterwards by means of ventilation, there are a few exceptions to this general and important rule.

If Acorns or sweet Chestnuts are preserved dry, they soon lose their vitality; the same is apparently true of the Mango, of Magnolias, the Chilian Araucaria, and some other plants. The reason of this has never been satisfactorily explained, and is the less obvious when it is considered that some of these seeds are oily, others resinous, and others astringent. On this account the treatment of them in a long voyage is merely empirical. It is, however, known that the most certain mode of conveying them is to place them in a situation where they are unable either to absorb moisture or to lose it. The best manner of effecting this is to pack them solidly in dry sand or nearly dry loam.

The manner of using sand or loam as a packing material is this:— Take a box, of wood sufficiently stout to resist pressure from within; strew three inches of sand or earth on the bottom; upon this place a thin layer of seed, taking care that the outside seeds are not nearer than three inches to the side of the box; then cover this layer with an

inch and a half or two inches of sand, according to the size of the seeds, and go on placing the seed and sand in alternate layers, till the box is full; place three inches more sand on the upper layer of seed, and fasten down the lid. With these precautions, such seeds as those above mentioned, and others of a similar kind, will travel for some months without injury. It is, however, necessary to observe, that the sand, or earth, must be pressed down very firmly, so that it may not be able to settle away from the sides of the box after the lid is fastened down.

For short periods perishable seeds may be packed in the manner described by Sir William Hooker, in a communication to the *Gardeners' Chronicle* (1844, p. 558). "Seeds of the Nutmeg-tree, by Mr. Lockhart, of Trinidad, were removed from the pulp and mace, packed in moist moss, and closed in a tin box almost hermetically. They germinated during the voyage, and threw out a radicle and a plumule to the length of an inch or more each, and apparently could not have come in a fitter state for planting with a prospect of their success." It may be supposed that in this instance either the decaying moss furnished the young nutmegs with food, or that there was not time for germination to be arrested. Probably they would have come still better in a bottle of moss kept damp, but supplied with air; as is done with aquatic seeds.

Dr. Royle states that in consequence of the difficulty experienced in sending to the Himalayas such seeds as the Filbert and Spanish Chestnut, he tried the effect of immersing such seeds in wax just melted, and met with complete success in repeated attempts. The Chestnuts and Filberts are described as arriving at Bombay, Calcutta, and Saharunpore, in a perfectly sweet and fresh state.

It seems worth inquiring whether all seeds would not preserve their vitality most perfectly if kept in an atmosphere of carbonic acid, which seems likely to oppose an effectual barrier to those changes which destroy seminal life. It would not be difficult to have bottles so contrived that after being filled with seeds their air might be exhausted and replaced by carbonic acid, which might be retained by hermetically sealing the aperture in the bottle. An attempt to verify this conjecture was made, in 1847, by the Horticultural Society, who sent seeds thus packed to New Zealand; but the result was never reported by the agents of the New Zealand Company. The experiment deserves a new trial. If it fails, the loss will be trifling; if it succeeds, the gain would be great, for the cost of bottles and

their proper preparation would bear no proportion to the value of the seeds preserved.

There is also on record (see *Gardeners' Chronicle*, 1844, p. 83) an interesting experiment by Mr. James M'Gall, at the time gardener to Colonel now Sir William Reid, the governor of the Bermudas. In those islands there are sudden and violent changes of climate, caused by the dry winds of the north shifting to hot southerly winds, bringing an atmosphere loaded with moisture. In consequence of this there is a great difficulty in preserving seeds, which, although they spring luxuriantly before the middle of summer, immediately afterwards lose their germinating power. Bottles, carefully sealed, and thick brown-paper packages are generally employed for their preservation, and kept in a cool and well-aired room. But although this preserves them from insects, yet the advantage does not appear to extend further. In the beginning of May last, Mr. M'Gall was induced, from the evenness of the temperature there, to put a bottle of Onion-seed, carefully sealed, which had arrived at Bermuda from Madeira in the beginning of February, into the bottom of a cistern of rain-water five feet below the surface of the earth. The cistern was cased with Roman cement, and had a free circulation of air above the cement, about seven feet from the bottom. On the 1st of November, about the usual time of sowing, this bottle was taken out and its contents sown, together with those of four other bottles of the same package, which had been kept in a cool warehouse during the summer, and of three others. In all cases the seed came up more or less; that in some of the bottles to the extent of about a fifth part, others of about a tenth, but in some scarcely at all. The seed, however, which had been kept under water came up regularly, and four or five days sooner than the others; the plants were strong, and not more than a fifth part of the seed failed. The seed in three of the bottles looked pale when opened, and several seeds were chipped or broken; the fourth bottle, in comparison with that taken out of the water, seemed equally fresh, though very few seeds sprung. It is no doubt possible that some of the seed was not good when first imported; but be that as it may, the seed kept under water came up as

quickly as new seed. This is a new fact, and if further experiments confirm Mr. M'Gall's experience, it may possibly be found that the best place for seeds on board ships bound to distant countries, is, as Sir William Reid suggested at the time, in bottles plunged in ship's tanks, where they may be exposed to a more uniform temperature than can be otherwise secured.

It must not be supposed from anything now said, that the conditions on which the preservation of seminal vitality appears to depend, are also such as in all cases govern the preservation of the life of perfect plants or their parts while torpid. The reverse is the fact; for as a general rule that dryness and exposure to air, which is favourable to seed, is prejudicial to the vitality of perfect plants, if too much prolonged.

No perfect state of a plant approaches the seed so nearly as the Bulb, for like a seed, it consists of a vital point, surrounded by a soft mass of tissue, which parts with its moisture slowly, in part in consequence of the obstacles offered to evaporation by the membranes that invest it, and in part by reason of the thickness of the sides of the cells of which its tissue consists. The precautions demanded in packing bulbs for long voyages are therefore much like those of seeds; except that bulbs will not bear dryness for a very considerable length of time. Two years form probably the longest period during which we have certain information that bulbs have been preserved in a torpid state.

We find the following report on this subject in the *Journal of the Horticultural Society*, vol. I. p. 79. Bulbs, experimentally prepared for a voyage to England, were received from India by the Court of Directors of the East India Company, and sent to the Garden for examination. One half of the bulbs were simply wrapped in cotton and packed in brown paper, while the other portion (of the same kinds of bulbs) was encrusted in a kind of white wax, and covered with cotton like the others. When received at the Garden, in June, 1844, those bulbs which were simply packed in cotton and brown paper had emitted roots on the journey, and the tops in most cases had grown considerably, while those coated with wax remained quite firm and as fresh as when first packed; although, according to the statement on the out-

side of the parcel containing them, they must have been confined in the wax three months. The bulbs transmitted in cotton began to grow first, but soon showed symptoms of debility; while those sent in wax did not move much before a month after they were potted, but then they grew strong and healthy. In one or two cases the bulbs perished in the cotton, while the same kind packed or coated in wax survived the journey.

In Cuttings nature has provided no special means of resisting exposure to unusual conditions and consisting, as they do, of but small masses of lax, thin-sided vegetable tissue, they much more readily part with their vitality than seeds or bulbs. Dryness is fatal to them; at the same time moisture in excess induces them, if in only a moderate temperature, to shoot and exhaust their vitality while packed up. The amount of moisture which they can best bear without risk of excitement in warm weather, is that which is natural to them, and no more. The attention of the gardener should therefore be directed to this point. It has been supposed that this might be accomplished by sealing the ends of cuttings with wax, or by dipping them in a solution of gum-arabic, or by enveloping them in sheet India-rubber; but although such precautions have enabled cuttings to travel from London to Simla without having lost their vitality, or, in some cases, having suffered much exhaustion during a journey of so many thousand miles, yet the success of such methods is too imperfect to satisfy the wants of colonists. It may be worth consideration whether a cutting would not retain its vitality longest if dipped in collodion, and then dried before being packed up. Of course the operator would take care that the cuttings selected are packed in some non-conducting material, such as cork, charcoal, or dry saw-dust.

Dr. Royle states that cuttings of Apples, Pears, and Plums, have been sent successfully from England to India, after having had their ends dipped in bees-wax. The following details were communicated by him to the *Gardeners' Chronicle* in 1843. Jargonelle Pear cuttings having been sent successfully from Falmouth to Bombay, a distance of 6000 miles, so as to arrive at their *destination in January*, and others, wrapped in cotton enveloped in India-rubber, after their ends were dipped in bees-wax, having reached Saharunpore 900 miles

up the country, it was determined to repeat the experiment in November; when cuttings are in a fit state to travel, and the temperature is lower than at any other time of the year, if we consider the time of their departure from this country, and that of their arrival in India. Some modification was made in the mode of packing. Instead of the ends being dipped in sealing-wax, the whole cutting was coated with bees-wax, then wrapped in cotton, and afterwards enveloped in India-rubber cloth. The packets were made up at the India House on the 30th of October, and must have left Falmouth on the 1st of November. From Bombay, which the mail usually reaches in about forty days, the cuttings had to be carried a land journey of about 1320 miles, to the Botanic Garden at Calcutta, which they reached on the 30th of December. A letter from Mr. Griffith states that three out of five Apple-cuttings seemed quite fresh. This experiment was made rather for the purpose of ascertaining how the mode of packing would answer, than with the hope of the cuttings succeeding completely. By the same mail cuttings were sent to the Botanic Garden at Saharunpore; where they arrived on the 28th of December. Dr. Jameson, on the 20th of January, made the following report of the state they arrived in: 1. Duchesse d'Angoulême, one specimen alive, the other dead, probably owing to the lateral twigs having been cut off and not sealed up. 2. Golden Pippin, with faint vitality, the pith discoloured, and the liber faintly green. 3. Glout Morceau, one dead, owing to the lateral branches having been cut off and not sealed; two alive, being devoid of them. 4. Malo di Carlo, in fine condition. 5. Gansel's Bergamot, upper end faint vitality; two specimens dead, the lateral twigs having been cut off and not sealed; three specimens in good condition. 6. Colmar, faint vitality upper end. 7. Jargonelle, eight specimens, all in good condition. From the above statement it will be seen that this transmission may be considered successful, and if cuttings void of lateral branches are sent, every one would probably have arrived in good condition.

Much of the success of these operations evidently depends upon the condition of the cuttings when they are packed up. If they are soft or unripe, no precaution will secure their safe arrival; if perfectly ripe, with their tissues consolidated, they will probably endure the journey. Mr. Beaton, a skilful practical gardener, has proposed the following method of preparing fruit-tree cuttings for long voyages. In the month of August, cut off the tips of a branch half-way between two buds or joints, and the force of the ascending sap will nearly heal over the wound in two months. Now, if you ring the shoot where you intend it to be cut off, you will

have all the strength and accumulation of this autumn's growth concentrated in the graft, as far as art can do it; and this, no doubt, will help, so far, their safe transmission. Besides, the store of vegetable matter, which will accumulate in the callosity over the ring, will be ready to break forth into roots as soon as the shoots are put into their natural element. Moreover, the partially healing over of the wounds in this way, will be almost sufficient to supersede the use of wax altogether.

In long voyages, the best way of sending live plants is no doubt in Ward's cases (see p. 221), which, if well constructed, answer perfectly, provided the plants are firmly secured in their places (a precaution often neglected), and not over-watered upon being finally closed; but the apparatus is expensive, and very liable to accidents at sea.

To pack otherwise live plants, not dry bulbs or mere cuttings, so as to endure the consequences of suspended growth, during long voyages, is an operation of considerable difficulty, unless they have hard skins, and a great store of moisture, like the *pseudobulbs of Orchids*, and the race of *succulents*. The latter are best preserved by being packed dry, and so separated that they cannot press together, and ferment, which is fatal to them.

The difficulty in question consists in the apparent impossibility of causing live plants to maintain their vitality for four or five months, except in a growing state, because of the power which the heats of the tropics possess of exciting vegetation, which can only be maintained when plants are fully exposed to light. If it were possible to retain plants in a torpid or dormant state, they might then be transported to any distance, enclosed in packing cases, like dead goods. Now, the conditions required to preserve a plant in a torpid state are these: the temperature must be low and equal, and the plant must be kept in the dark. If these conditions can be fulfilled, a plant may be preserved, probably, for a twelve-month without growing, and certainly for six months. The great difficulty lies with its natural excitability, which leads it, whenever possible, to renew its growth at an appointed

time, after which very extraordinary measures are required to repress its desire to grow. It is, however, possible to do this. If a plant—a Vine—after having been rested in the natural way for four months, is introduced into a forcing-house, it shoots freely; if the rest has extended to six months, it pushes with still greater force; but if it has only rested for two months, its excitability is less easy to arouse; and supposing the period of repose to have been only a week or two, the renewal of its growth takes place with difficulty, and feebly. It is therefore evident, that in a case where it is important to repress excitability, the plant should be operated upon as soon as possible after it has naturally gone to rest. Accordingly, it has been found, that if plants in this country are packed up in the month of November, they may be made to travel for considerable spaces of time if kept damp, tolerably cool, and closed up from light, which is the great stimulating power. In this way Camellias have been sent, by Cape Horn, to Lima, and other plants to the Australian continent, by Messrs. Loddiges.

The mode of proceeding is this: plants, three or four years old, with ripe, well-formed wood, are, in November or October, placed in layers, in a stout chest, and well packed with an abundance of sphagnum, trodden down *as tight as possible*, so that no open spaces are left in the interior, but that the whole mass is firm and compact. By these means the plants are surrounded by a substance which conducts heat very badly, and will scarcely part with its moisture at all under such circumstances. The chest is then securely fastened down, and no further care is demanded, except insuring its being placed *between decks*, in a ventilated situation, during the voyage. It would, however, we conceive, be an improvement if the chest of plants were guarded by another case, the space between the two being filled with charcoal, and the whole enclosed in a *polished tin* cover; for by these means the variations of temperature would be most securely guarded against.

The success of operations of this kind will, after all, depend greatly upon the specific vitality of plants. In this respect they vary remarkably, as the following well-attested facts may serve to show. We are indebted for them to M. Pépin, Superintendent of the Jardin des Plantes.

"The Orange, as is well known, is capable of resisting bad treatment

for a long period; but there are no known examples which offer so convincing a proof of its strength as the following:—In 1833 I saw an Orange-tree in a garden in Normandy, whose trunk was 6½ inches in diameter at two feet from the surface of the soil, and nearly two yards high before it branched. This plant had been neglected for a long time; water was frequently withheld during the summer, and there being no convenient shelter for it in the winter, it died back every year. The tub in which it had been planted at last fell to pieces with age, and then the plant was removed. Reduced to almost nothing by the successive loss of its branches, the trunk was preserved for two years in the corner of a cellar; after which the principal branches and roots were cut off near their origin. The stem of this Orange remained in the same place for four years more, laid horizontally on the ground, to serve as a stage to set casks on; and during these six years it showed no indication of vegetating. At the end of this period the bark was observed to be still green, and in 1831 the trunk was planted with care in a tub filled with rich light vegetable mould. In this state it remained for some months, no more water being given to it than was strictly necessary; soon afterwards swellings were seen on several parts of the bark, and a number of rootlets appeared about the sections of the old roots, from which new ones were developed. The trunk also showed some little productions of cellular tissue, from which new buds proceeded the following year. All those which were imperfect or crowded were rubbed off, and in 1837 this tree had a vigorous well-formed head and fine foliage; and since that time it has continued to flower every year.

"In 1762, or 1764, the Count de Charolais had a fine estate in what is now called the quartier Montmartre, the garden attached to which was magnificent, and kept with a great deal of care; and the Orangery, which was one of the finest of that age, contained 300 large Orange-trees. M. de Charolais was a great amateur, and believed that these trees were as beautiful as those at Versailles, or in the other royal gardens. Being exiled from Paris by the Parliament, he, at his departure, had all the doors and passages to his hotel closed, and the Oranges remained immured in the Orangery without air and water for the six years during which his exile lasted. M. Audebert, the gardener attached to the house, was ordered not to go into the plant-houses, nor even into the garden. When M. de Charolais returned, the windows and doors of the Orangery were opened, and what was the despair of the gardener at finding the trees, which previously had been the admiration of everybody, changed to dry sticks, dried up, and completely deprived of leaves; in fact, to all appearance dead! Notwithstanding this, M. de Charolais wished his Oranges to be placed in the same order that they were before his exile. On examination, the roots were found to be in the same state as the branches; they were cut back

close, cleaned, and those which were quite dead removed. A mixture of good well-sifted earth was prepared, after which the trees were replanted in the same tubs; a thick stratum of potsherds being put in first. Water was applied to the trees with the greatest caution; the branches which formed the head were either drawn together or cut off to within a yard of the stem, and the two or three years-old wood was cut back to the young branches. This operation being performed, they remained for a year without exhibiting any sign of vegetation; but the following year, one hundred out of three hundred developed buds. M. Riché, who saw them, assured me that they were very vigorous, and bid fair to become fine trees.

"When woody plants are placed in analogous conditions, they can, notwithstanding they are deprived of a large portion of their organs of nutrition, live for a long time. It will be observed, that the trunk of the Orange which remained for several years in the cellar, was in a more favourable position for absorbing moisture by its bark, than those Oranges which were for six years in a conservatory hermetically sealed, each planted in a separate tub, the earth in which, without doubt, was much drier than the soil and atmosphere of the cellar. I have also made experiments in a somewhat similar situation as the cellar of which I have spoken. I have placed stems there with or without roots, after having cut the branches to three or four inches in length, and the roots in the same manner; for without this precaution all that I have tried have not lived more than a year. The situation was moist rather than dry, and almost dark. Different stems of trees so treated have developed adventitious buds for several years, and being afterwards replanted, they have grown well without showing any remarkable alteration. Two stems of Morus alba from 2 to 3 yards long, one being 6½, the other 4 inches in diameter, produced, during four years, in this situation, adventitious buds, from which young branches 4 to 6½ inches long sprung, furnished with small leaves; but these young shoots were partly destroyed during the winter by the moisture. Two pieces of Ulmus campestris, of nearly the same thickness, have grown during five years. Two pieces of Robinia pseudo-acacia, one 7 inches in diameter, and the other 5½, have both vegetated for three years, as well as a common Pear-tree 4 inches in diameter; so also the stem of a Whitethorn 3¼ inches in diameter. Populus virginiana and P. nigra, 6½ inches in diameter, have produced buds during five years.

"I have made the same experiments on some pieces of Willow from 1 to 2 inches in diameter; they also produced new buds. Moreover, there formed, every year, on these stems, at intervals, productions which then dried down to the wood, and were soon afterwards covered with fungi and mouldiness; but notwithstanding this, buds were developed on the green parts, and these continued to grow, like the preceding.

"M. Bové, in his relation of a botanical journey in Egypt in 1829, says, 'in visiting the estate of Ibrahim Pacha, one of his directors pointed out, near the village of Kouba, a stock of a Locust-tree (Ceratonia siliqua), which he said had been planted about 300 years. The tree was cut down by the French, during their invasion; its roots remained in the earth, and gave no indications of vegetation till the Pacha caused the earth to be broken up about it in 1826, and a well to be sunk, the moisture from which induced it to throw up three branches, which in three years were three or four yards high, and almost 12 inches in circumference at the base. Even flower-buds seemed disposed to show themselves on the branches. Thus this stock remained buried for 30 years without perishing, and probably without ceasing to increase in size. This surprising fact may be placed by the side of that mentioned by M. Dutrochet of a kind of Pine, whose root year after year produced new layers of wood for 90 years, without any existence of a stem. M. Gaudichaud has also made known a remarkable instance of the duration of life in a shoot of Cissus hydrophora, which after being dried three years in a herbarium, and even after being placed in an oven, furnished cuttings, by which it has been propagated in the hothouses of the Museum of Natural History.

"I have noticed that fleshy roots, like those of Pæonies, do not produce tops when they are cut, except those of Chinese Pæonies. The same thing occurs with bulbous and fusiform roots, deprived of their buds or eyes, although others produce tops, although they have been cut into several pieces. There are perennial grasses whose roots are preserved for more than a year in the earth without emitting roots. The same takes place with the rhizomes of many Asters, Solidagos, Cinerarias, and Helianthuses, and a great number of other genera. Analogous facts are remarked among succulent plants, and such monocotyledons as Dracæna, Arads, &c. I have had for eight years shoots of a Cereus peruvianus, which, in the free air of a room, left without water or earth, produced every year new roots about an eighth of an inch long, and were thus preserved for a year or two before they dried up. During the first three years these shoots grew an inch or more every year; for two years afterwards they lived, but did not grow. Many Cactus cuttings remain three or four years without any appearance of vegetation, although the pots in which they are planted are filled with roots. Shoots of Cactus phyllanthoides, under similar circumstances, every year formed a portion of a stem, at the extremity of the old one, and on these stems two flowers have been seen to blossom, after which the old shoot became yellow, then dried, became tough, and what had grown upon it gradually perished. I have also preserved without water shoots of Stapelia asterias, variegata, cæspitosa, and hirsuta, and they have all produced flowers; and the same has happened with Aloes, which have lived for three or four years, producing new roots, and forming buds along their whole length."

In conclusion, M. Pépin gives a list of plants, fragments of whose roots have remained buried and torpid for several years. The more remarkable are the following:—Bignonia radicans, 10 years; Gymnocladus canadensis, 10; Locust trees, 10; Ulmus campestris, 6; Dodartia orientalis, 8: Euphorbia dulcis, 6; Hoffmannseggia falcata, 10; Solanum carolinianum, 10; Pulmonaria virginica, 5; Urtica cannabina, 4.

It is almost needless to add, that with plants like those mentioned by M. Pépin, very slender precautions suffice to insure their living through the longest voyages, if prepared in the manner adopted by Messrs. Loddiges, as already described, and that his statements sufficiently establish the fact that plants possess different powers of vitality, those of some being infinitely greater than what belongs to others.

CHAPTER VIII.

OF PROPAGATION BY EYES AND KNAURS.

THE power of propagating plants by any other means than that of seeds depends entirely upon the presence of leaf-buds (Fig. XXXIV.), or, as they are technically called, "eyes," which are in reality rudimentary branches in organic connection with the stem. All stems are furnished with such buds, which, although held together by a common system, have a power of

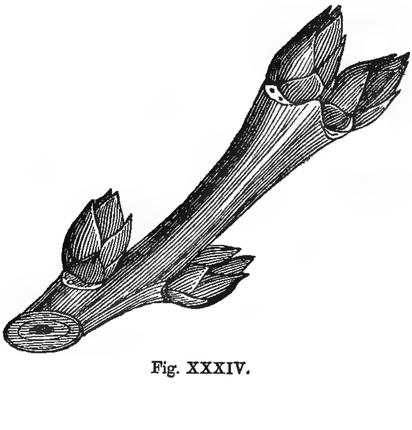

Fig. XXXIV.

independent existence under fitting circumstances; and, when called into growth, uniformly produce new parts, of exactly the same nature, with respect to each other, as that from which they originally sprang.

Under ordinary circumstances, an eye remains fixed upon the stem that generates it. There it grows, sending woody

matter downwards over the alburnum, and a new branch upwards, clothed with leaves, and perhaps flowers; but it occasionally happens that eyes separate spontaneously from their mother stem, and when they fall upon the ground they emit roots and become new plants (p. 44, Fig. X.). This happens in several kinds of Lily, and in other genera.

Man has taken advantage of this property, and discovered that the eyes of many plants, if separated artificially from the stem and placed in earth, will, under favourable circumstances, produce new plants, just as such eyes would have done if they had spontaneously disarticulated; hence the system of propagation by eyes, an operation employed only to a limited extent in actual practice, but which in theory seems applicable to all plants whatever. The species most generally so increased are the Potato and the Vine. Of the latter, the eye, with a small portion of the stem adhering to it, is commonly used as the means of obtaining young plants; being placed in earth, with a bottom heat of 75° or 80°, and kept in a damp atmosphere, it speedily shoots upwards into a branch, and at the same time establishes itself in the soil by the development of the requisite quantity of roots. In order to insure success in this operation upon the Vine, it is only necessary that the eye should be dormant, and that a small piece of well-ripened wood should, as has been already stated, be separated with it; it will then grow in much the same way, and under the same circumstances as a seed. There is no doubt that many plants could be thus multiplied as easily as the Vine, but it is equally certain that a far larger number cannot be so increased. The reason is, probably, that such eyes are not sufficiently excitable, and that consequently they decay before their vital energies are roused; and, in addition, that they do not contain within themselves a sufficient quantity of organisable matter upon which to exist until new roots are formed, and capable of feeding the nascent branch.

Mr. Knight's explanation of this, although in part applicable to cuttings only, yet seems to deserve being introduced in this place. "Every leaf-bud is well known to be capable of extending itself into a branch, and of becoming the stem of a future

tree; but it does not contain, nor is it at all able to prepare and assimilate, the organisable matter required for its extension and development. This must be derived from a different source, the alburnous substance of the tree, which appears the reservoir, in all this tribe of plants, in which such matter is deposited. I found a very few grains of alburnum to be sufficient to support a bud of the Vine, and to occasion the formation of minute leaves and roots; but the early growth of such plants was extremely slender and feeble, as if they had sprung from small seeds; and the buds of the same plant, wholly detached from the alburnum, were incapable of retaining life. The quantity of alburnum being increased, the growth of the buds increased in the same proportion; and when cuttings of a foot long, and composed chiefly of two-years-old wood, were employed, the first growth of the buds was nearly as strong as it would have been, if the cuttings had not been detached from the tree. The quantity of alburnum in every young and thriving tree, exclusive of the Palm tribe, is proportionate to the number of its buds; and if the number of these were, in any instance, ascertained and compared with the quantity of alburnous matter in the branches and stem and roots, it would be found that nature has always formed a reservoir sufficiently extensive to supply every bud. But those of a cutting, under the most favourable circumstances, must derive their nutriment from a more limited and precarious source; and it is therefore expedient that the gardener should, in the first instance, make the most ample provision conveniently within his power for their maintenance, and that he should subsequently attend very closely to the economical expenditure of such provision." (*Horticultural Transactions*, ii. 115.)

A practical mode of carrying out these views consists in detaching a mature leaf along with the bud which is to propagate.

The mode of doing this has been thus described by Mr. R. Markham, the very experienced gardener at Hewell Grange:—"The Camellia pæoniflora being the strongest growing sort with which I am acquainted, is the one I select for the purpose. In March, with a sharp knife, I cut

off as many leaves close to the branch as I want, *taking, of course, the buds off with them.* The leaves are potted immediately in 48-sized pots, in peat and sand, and are placed about one-third their depth into the soil, and the pots are then plunged into a tan-bed where no fire-heat is employed; they are covered with a hand-glass, kept moderately moist, and shaded when necessary. These leaves strike root, grow vigorously, and in two seasons make good stocks for grafting on. This mode of raising Camellia stocks is very convenient, for it is often easier to procure leaves than grafts, and the plan answers well when leaves are sent from a distance. In April, 1843, a blossom of a new double Camellia was sent to me; it had travelled upwards of 300 miles, and was so dry that I could not discover its colour; there were, however, two or three leaves attached to it, one of which was treated as above, and I have now from it a very strong plant, five feet six inches in height, producing nine flower-buds ready to expand. The plant has been stopped twice in order to cause it to throw out branches, which are now eleven in number; the circumference of the stem is an inch and a half at the bottom. I likewise raise Orange stocks in a similar manner: the leaves are cut off in August, and are potted but not covered with hand-glasses. The stocks which I use for Orange-grafting are Citrons, which being strong growers, make excellent plants by the following summer. The Citrons, I imagine, may, however, be grown much quicker by putting in the leaves in February instead of August. I have no doubt that the plants will be sufficiently strong to be grafted by the end of July or early in August."

This is a very different process from propagation by mere leaves, the subject of the next chapter.

In the Potato the requisite provision of organisable matter is always secured, in consequence of the great difficulty of separating an eye of that plant, without fragments of the fleshy tuber adhering to it.

The provision of alimentary matter may, however, be, in some cases, disadvantageous, by promoting too great a development of stems and leaves, of which the Potato itself is an instance. Theoretically, the more nutritive matter there is for the eyes, the greater crop there will be, *cæteris paribus,* and so there probably is of leaves and stems; and it would seem that whole potatoes should be more advantageous to plants than sets. But I have proved by a series of numerous experiments, that the weight of potatoes is per acre greater, under equal circumstances, from sets than from whole tubers, by upwards of from

seven cwt. to three tons per acre; and considerably more, on comparison of the clear produce, after deducting the weight of sets employed in both cases. (*Hort. Trans.*, n. s., i. 445, and ii. 156.) In these instances, I supposed the rankness of the vegetation from the whole tubers to be the cause of the diminished crop, for the stems not only expended their strength in self-augmentation, but were unable to support themselves, and were blown about, laid, and broken by the wind.

While, however, in such plants as the Potato, all the eyes are equally capable of forming new tubers, it is found by experience that they do so with different degrees of rapidity, according to the age of that part of the stem or tuber which furnishes them. It is stated by a writer in the *Gardener's Magazine* (vol. i. p. 406.), that it is well known in Lancashire to some cultivators of the Potato, "that different eyes germinate and give their produce, or become ripe, at times varying very materially, say several weeks, from each other; some being ripe or fit for use as early as the middle of May, and others not till June or July. This will be understood by reference to the accompanying sketch. The sets nearest the extremity of the Potato (Fig. XXXV. *a*) are *soonest ripe*, and, in Lancashire, are planted in warm places in March or the beginning of April, and are ready for the market about the 12th or 15th of May. The produce of the next sets (*b*) is ready in about a fortnight after, and that from the root end (*c* and *d*) still later. These root end sets (from *b* to *d*) are usually put together, and the extremity of the root end is thrown aside for the pigs." This fact, if correctly stated, shows, not that the youngest eyes, or those nearest the point of the Potato, are the ripest, which is impossible, but that they are more excitable, and consequently grow more rapidly than those at the middle or base.

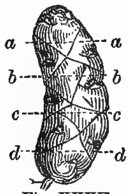

Fig. XXXV.

Besides the cases of propagation by eyes now mentioned, there is another of which a notice is given by Signor Manetti (*Gardener's Magazine*, vii. 663.), as practised in Italy upon the Olive. It appears that, from old Olive-trees, certain knots or excrescences, called *uovoli*, are cut out of the bark, of which a

portion is left adhering to them, and, being planted, grow into young Olive-trees. Of these we have no further account; but it is evident that the *uovoli* are no other than our knaurs (Fig. XXXVI.), already spoken of under the name of *embryo buds;* concretions found in the bark of many, and probably of all, trees, and supposed to have been adventitious buds developed in the bark, and, by the pressure of the surrounding parts, forced into those spheroidal woody masses in the shape of which we find them. They often present an oblong or conical form,

Fig. XXXVI.—Knaurs.

are sometimes collected into clusters (Fig. XXXVI. *a*), and may exhibit little or no appearance of a tendency to further growth. It is, however, not uncommon to find them lengthening into branches, as is shown in the Poplar (Fig. XXXVI. *c*), for which I am indebted to Sir Oswald Mosley; and although they have never yet been used for the purposes of propagation, except in the case of the Olive, there seems to be no reason why they should not be so employed, if any necessity were to arise for them. The real amount of their powers of growth is unknown, and would be a good subject of investigation.

It will have been seen that the mode of propagation here explained is analogous to that by seed, both having for their

object the increase of a given race. There is, however, this very important difference, that while eyes multiply the individual, seeds only multiply the species.

For example the Green Gage Plum is a *variety* of the *species* Prunus domestica. The seed of a Green Gage will undoubtedly produce Prunus domestica, but not a Green Gage. On the other hand an eye (cutting or graft) of the Green Gage Plum will increase that particular variety.

"Although it occasionally happens that some one branch of a plant disagrees from the rest of the branches in certain small peculiarities of growth, such as the colour of the leaves, the doubleness of the flowers, the character of the fruit, &c., thus acquiring the properties of a special variety, yet this is an exception to rule. Every part detached from a plant continues to correspond with its parent after its separation, and for this reason propagation by division affords the means of multiplying varieties which either could not be propagated at all by seed, or only with uncertainty." *Mohl.*

It has, however, been generally asserted that varieties multiplied for many generations by eyes (cuttings or grafts) gradually degenerate, become diseased, and disappear; whence it is said that propagation by eyes can only be employed with safety for a few generations. For this idea there seems to be no sufficient foundation; but as it will be further examined in Chapter XVII., I content myself for the present with quoting the opinion upon the subject of Prof. Mohl, the greatest of modern German physiologists. "Thousands of experiments," he observes, "have shown that the young shoots of old trees, when used as grafts, slips, &c., furnish as strong plants as the shoots of young trees. Even in the Palms (Phœnix dactylifera) experiment has proved that the apex of the stem, when its vegetation begins to slacken in an old tree, grows again into a strong tree when cut off and planted in the earth. Not one single experiment speaks in favour of the opinion promulgated by Knight, that all parts of a tree have a common end to their life, and that the different trees which have been raised from one and the same tree by grafts, decay about the same time as the parent plant. A whole series of cultivated plants (I will only mention the Vine, the Hop, the Italian Poplar, and the Weeping Willow) are propagated by division, without any

decreased power of vegetation ever being seen. Nothing was in greater contradiction to the laws of vegetable life, than the frequently expressed opinion, that the Potato disease of recent years was to be ascribed to a degeneration of the Potato plant, arising from the unceasing propagation by tubers."

CHAPTER IX.

OF PROPAGATION BY MERE LEAVES.

In the beginning of the last century, Richard Bradley, a Fellow of the Royal Society, published a translation from the Dutch of Agricola, of a book upon the propagation of plants by leaves, in which it was asserted that, by the aid of a mastic invented by the author, the leaves of any plant, dipped at the stalk end into this preparation, would immediately strike root; and the book was adorned with copperplates exhibiting both the process and its result, in the form of fields stuck full of Orange leaves growing into trees.

One of these plates illustrates, "How by means of fire and mummy, leaves, twigs, buds, and branches may be turned into shrubs and trees by planting them in the ground."

"Having observed," he adds, "that the leaves of some plants may very well be used instead of joints or shoots, I shall now undertake to show how the leaves take root. The curiosity for cultivating vegetables, it is well known, has long since been carried so far as to occasion an attempt to raise a tree from a leaf, just as F. Mandirola made the experiment with a Lemon-tree-leaf. His words upon this subject, taken out of his writings, are as follows:—'I tryed a masterpiece, to wit, to plant Citron, Lemon, and such like leaves after the following manner. I took for that purpose a sort of little flower-pot full of the best-sifted earth; I planted in it some leaves of those kinds of trees, with their stalks so deep that the third part of the leaf was covered with earth; over that pot I fastened a small pitcher full of water, so as that it might drop directly down into the middle of the pot, and the hollow which was made by the falling of the drops I continually filled up with fresh earth: thus they cost me but a little trouble, and they all shot up and grew very well. I pursued it with the greatest patience in the world, and found that through a too often dropping of the water, the leaves began to rot, and so wasted away of themselves by little and

little, so that at last nothing was left but the stems; but it having been observed since, that from the callous matter that came forth at the bottom, both roots and branches shot out, it appears that *all exotic leaves* may at any time be converted into trees. For this operation I make choice of the months of July, August, and November; but those who have stoves and greenhouses may perform it even in winter, and in that case they shoot the better in the spring. Those who have a mind to do it in the spring will have some success; but it is not so very sure, which ought to be chiefly ascribed to the inconstancy of that season.'"

Although this work was absurd, yet it originated in the discovery that the mere leaves of some plants will grow under special circumstances; a fact often supposed to be much more rare than it really is. In Professor Morren's French translation of my *Outlines of the First Principles of Horticulture*, Rochea falcata* is named as producing adventitious buds from the upper side of its leaves; and the Orange, the Aucuba, and the Fig, as other instances of leaves which will multiply their species: the power of Bryophyllum to do the same thing is familiar to every one. Echeverias have been remarked to grow immediately from the leaves that naturally fall off even its flower-stalks. Hedwig found the leaves of the Crown Imperial, put into a plant press, produce bulbs from their surface. There is a well-known case of the same effect having been observed in Ornithogalum thyrsoideum. Mr. Auguste de St. Hilaire mentions an instance of leaf-buds generated by fragments of the leaves of "Theophrasta," which had been buried by M. Neumann, chief gardener at the Garden of Plants at Paris, and of young Drosera intermedia. Mr. Henry Cassini is said to have seen young plants produced by the leaves of Cardamine pratensis; English botanists know that offsets spring from the margins of the leaves of Malaxis paludosa; in our stoves we see Ferns of many kinds, especially Woodwardia radicans, propagating themselves by offsets from the leaves; Mr. Turpin tells us that floating fragments of Watercress leaves, cut up by a species of Phryganea for its nest, "produce presently from their base, and below the common petiole, at first two or three colourless roots, then in their centre a small

* See, also, De Candolle's Physiologie Végétale, ii. 672.

conical bud, green, in which are found, or rather from which successively arise, all the aërial parts of a new Watercress plant, while the roots multiply and lengthen." (*Comptes rendus*, 1839, sem. 2., 438.) Mr. Flourens also mentions a case of Purslane, whose leaves, divided into three, produced as

Fig. XXXVII.—Scale of Zamia sprouting.

many new plants, each having a root, stem, and leaves. In the *Transactions of the Horticultural Society*, is an account of a Zamia, each of whose scales (Fig. XXXVII.) produced a new

plant, when the central part of the stem was decayed. Finally, the following case is named in the same work (vol. v. p. 242) by Mr. Knight:—"In an early part of the summer, some leaves of Mint (Mentha piperita), without any portion of the substance of the stems upon which they had grown, were planted in small pots, and subjected to artificial heat, under glass. They emitted roots, and lived more than twelve months, having assumed nearly the character of the leaves of evergreen trees; and upon the mould being turned out of the pots, it was found to be everywhere surrounded by just such an interwoven mass of roots, as would have been emitted by perfect plants of the same species. These roots presented the usual character of those organs, and consisted of medulla, alburnum, bark, and epidermis; and as the leaf itself, during the growth of these, increased greatly in weight, the evidence that it generated the true sap which was expended in their formation appears perfectly conclusive."

In gardens, we have many other cases of the same kind. Hoya is a common instance, and three others are here figured (Fig. XXXVIII.); viz., Gesnera (*a*), Clianthus puniceus (*b*), Gloxinia speciosa (*c*). In these, and all such cases, the first thing that happens is an excessive development of cellular tissue, which forms a large convex "callus" at the base; from which, after a time, roots proceed; and by which eventually a leaf-bud, the commencement of a new stem, is generated.

It is not surprising that leaves should possess this quality when we remember that every leaf does the same thing naturally, while attached to the plant that bears it; that is to say, forms at its base a bud which is constantly axillary to itself. Leaves, however, have not been often employed as the means of propagating a species; and it is probable that most leaves, when separated from their parent, are incapable of doing so, for reasons which we are not as yet able to explain. The most common case of their employment is in the form of the scales of a bulb, which will, with some certainty, produce new plants under favourable circumstances. Those circumstances are, a strong bottom heat, moderate moisture, and a rich stimulating soil.

When plants are produced by leaves under ordinary circumstances, the conditions most favourable to their doing so are of

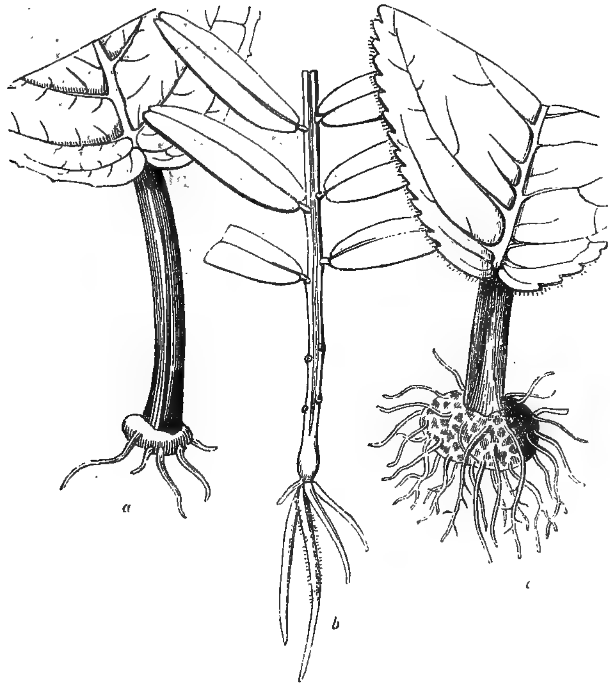

Fig. XXXVIII.—Rooting leaves of *a*, Gesnera; *b*, Clianthus puniceus; *c*, Gloxinia speciosa.

the same nature. A moderate amount of moisture prevents their dying from perspiration or perishing from decay; a good bottom heat stimulates their vital forces, and causes them to exercise whatever power they possess; and, in addition, they are covered by a slightly shaded bell-glass, which maintains around them an atmosphere of uniform humidity, and, at the same time, cuts off the approach of those direct solar rays, which, acting as a stimulus to perspiration, would have a tendency to exhaust the leaves of their fluid before they could organise, at their base, the new matter from which the leaf-bud is eventually produced.

The rationale of this operation seems to be as follows.

No plant can form a new individual without first organising a bud. That *must* be in all cases the first step in the process of propagation. Now buds are known to spring exclusively from the soft pulpy or cellular matter that constitutes the flesh of plants, and not from their solid woody parts. This cellular matter is formed by Nature out of organisable fluids produced by the leaves, and by the leaves only, or their equivalent, as in the instance of the green bark of the leafless Cacti. Hence it follows that leaves are really the great agents of propagation in any case, whether layers, cuttings, or other forms of multiplication are had recourse to; for the power possessed by the parts of plants so named is derived immediately and exclusively from the leaves. But leaves in their natural state are connected with the stem by a peculiar and admirable mechanism, which insures their being continually and abundantly supplied with food out of which they may prepare the organisable matter that is in the first instance to engender cellular substance and afterwards a bud. If this mechanism is disarranged the leaf dies, or becomes unhealthy, and loses its bud-creating power. No disturbance of the mechanism in question can well be greater than that which separates the leaf from its stem, and therefore the chances of the leaf dying are great in proportion. But if, notwithstanding the separation of a leaf from its supply of food, means can be found to nourish it in some other manner, it may be kept alive; and if its vitality can only be preserved long enough, it must necessarily go on forming cellular matter, which again will obey that irresistible impulse which compels a bud to be engendered; and the bud being formed, a new plant will follow as a matter of course. The problem to solve is how to nourish a leaf as well as it was nourished by its parent. To that question propagators have exclusively to direct their attention, for there is no fact more certain in nature than that if the supply of proper food to a leaf is but kept up, form a new plant it inevitably must.

The difficulties connected with the question will perhaps be diminished, if we first ascertain what the means are by which certain leaves have been made to grow already. Mandirola tells us that he struck his Lemon and Orange leaves by

keeping the soil in which they were inserted continually wet; that those of July, August, and November struck best, and the spring leaves worst. Mr. Knight, who made the leaves of the common Peppermint grow, planted them in the early part of summer, in small pots, in heat, under glass. Bits of Water-cress leaves will strike root freely; but it is only such as float on the water. The common way of converting succulent leaves into plants is to place them on damp sand, under a bell-glass, or without one, according to the nature of the leaf. These practical details show that water is employed to replace the sap on which leaves usually subsist. But other points are of equal importance.

Of these, the first is to select leaves at the right season: if they are too young, they are not capable of feeding themselves when sundered from their parent; if too old, their vigour is impaired, and their vitality on the wane. Skilful propagators therefore take care to employ leaves fully grown, but not beginning to change colour; such as those found about the middle of a branch in full vigour.

A second precaution is the application of more warmth than the leaves had been previously subject to. All the vital energies of plants are increased under the influence of heat, and in a case of this sort nothing must be neglected that will stimulate the flagging powers of life. Aided by warmth the leaves form their secretions faster, generate their cellular matter faster, and so form their callus sooner. Quickness of action is of great importance in such an operation as leaf-striking.

A third condition will be perfect equability of moisture; the leaf must not be expected to feed by the end of its stalk exclusively, but food must be presented to its whole surface; not, however, too much nor too little. If too much, the leaf will be unable to digest it, and will perish of repletion; if too little, the cells will collapse, their excitability will be impaired, and there is an end of the experiment. Herein consists the main difficulty of the operation, for leaves have very different powers of taking in food and digesting it; and nothing but experience can adjust exterior conditions to the peculiar organization of species.

The last point to which attention need be directed is the necessity of exposing leaves to the free influence of light. In natural conditions, a leaf does something more than feed—it breathes. The one act is as needful as the other. In the light respiration goes on freely; in the dark it is suspended, or at least is much impeded. But in sunlight a leaf not only breathes, but loses water—a circumstance of no importance to it whilst upon its parent plant, because all loss is then made good from instant to instant, through the veins which pass out of the stem. Separated from its natural source of supply, the condition of the leaf is entirely altered; and it cannot be expected that the loss occasioned by evaporation should be as equally and instantaneously compensated. The only way of meeting this difficulty is by covering leaves with bell-glasses, whose edges are sunk in the damp sand or earth, in which the leaf is to be struck. In this way, the leaf will always be in contact with moist air. Under a bell-glass the perspiration of a leaf in sunlight is then so much diminished as to be of no importance, because, if the leaf is losing water, it is also absorbing it, and this as copiously as its necessities demand. It may therefore be exposed to the conditions favourable to its breathing, without danger of injury.

The great objection to employing leaves as a means of propagation consists in their unwillingness, in many instances, to form a bud as well as roots. A leaf of Hoya carnosa has been known to remain without change for nine or ten years, although it produced roots. The leaves of roses strike freely, but will not bud. These peculiarities belong to the nature of species, and are not susceptible of explanation.

The following is Mr. Neumann's practical account of the manner in which his experience as a propagator teaches him to proceed with leaves:—

"A single leaf cut near the stem and planted, is sufficient, in some plants, to produce new individuals. The leaves intended for this operation ought not to be pulled off the stem; there is no need of taking away the eye which shows itself at their axil; in this method of striking by cuttings it is not the eye which developes itself, as many people imagine; the effect which takes place is similar to that produced when cuttings are struck from the branch of Abies. It is upon the

cluster of small bulblets which form on certain parts of the leaf, that the shoot shows itself. Fig. XXXIX. *a*, indicates at what place we may cut the leaf without hurting the plant; the leaf being placed in the earth forms a callus at its base, Fig. XXXIX. *b*, whence the roots, and consequently more shoots spring up.

"Leaves intended for cuttings should be taken about the middle of a branch; the result is more certain than if we choose the lower leaves. Gloxinia, Bryophyllum, Lilies, &c., multiply well by such cuttings. If we wish to get on very quickly, the midrib on the lower face of the leaf may be broken in several places, without injuring the limb, and so

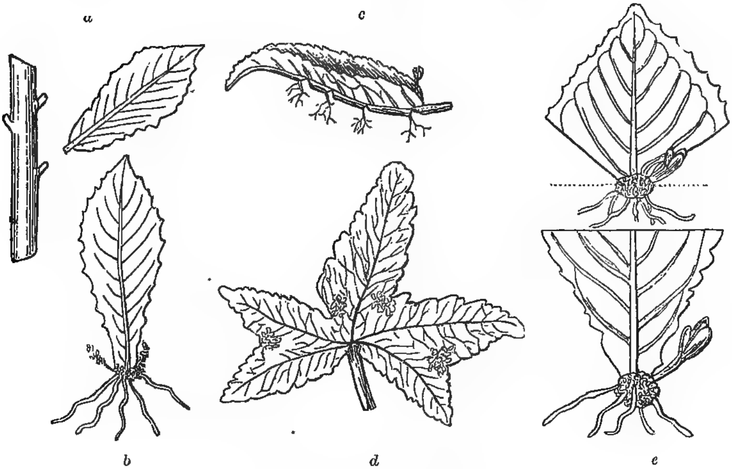

Fig. XXXIX.—Cuttings of leaves.

lightly that the broken places can scarcely be distinguished; the lower face of the leaf is then placed on the earth of a pot. Soon at each fracture a little callus developes itself, which gives rise to roots, as is seen in Fig. XXXIX. *c*. Some leaves, when employed as cuttings, send out roots and buds at each incision, as, for example, in Hemionitis palmata, Bryophyllum, &c. Fig. XXXIX. *d* shows how this effect is produced.

"Cuttings of leaves are often a long time before they show any sign of succeeding; the care which they require is in consequence of their delicate nature; most especially must attention be paid to burying the end of the petiole, or the base of the leaf. When their buds are strong enough they may be accustomed, by degrees, to the free air of the greenhouse, in which they are to remain, then treating them like cuttings from branches.

"Having succeeded with the leaves, of which I have just spoken, I

tried, in 1839, to multiply Theophrasta latifolia with its leaves cut in two, with which I made two cuttings; these portions took root and developed buds, as is seen in Fig. XXXIX. *e*. This experiment evidently proves that some plants may be reproduced by cuttings of the midrib of their leaves. The primitive bud, as I have remarked, rises from the callus above the root which first shows itself, and about 1-16th of an inch from the base of the midrib. The dotted part, shown in the upper half of the annexed leaf, *e*, was removed in order to put the leaf into a little pot, but this did not prevent the success of the cutting."

CHAPTER X.

OF PROPAGATION BY CUTTINGS.

THIS, which is the most common of all modes of artificial propagation except grafting, depends upon essentially the same principle as propagation by eyes; that is to say, the pieces of a plant called cuttings possess a power of growth in consequence of their bearing leaf-buds or eyes upon their surface. In striking by eyes, we have the great difficulty to encounter of keeping the eye active till it has organized roots with which to feed itself; the earth furnishes such a supply unwillingly or unsuitably, nature intending that the bud should, in the first instance, be supported by the soluble nutriment ready prepared and lodged in its immediate vicinity, in the pith or some other part of the stem. For this reason, cuttings, which consist of eyes and the part containing their proper aliment, usually strike root more freely than eyes by themselves.

This being so, it is plain that a cutting is only capable of multiplying a plant when it bears buds upon its surface; and as the stem is the only part upon which buds certainly exist, so the stem is the only part from which cuttings should be prepared. And again, as the internode, or that space of the stem which intervenes between leaf and leaf, has no buds, their station being confined to the axil of the leaves, a cutting prepared from an internode only is as improper as one from the root. It is no doubt true, that we constantly propagate plants from pieces of what are called roots, as in the Potato, or the Scirpus tuberosus; but such roots are, in reality, the kind of stem called a tuber, and, in like manner, other cases of

similar propagation are also successful, because the part called a root is, in reality, an underground stem covered with the rudiments of leaves, to each of which an eye belongs. The Rose, the Lilac, and many other plants have subterranean stems, cuttings of which will therefore answer the purpose of propagation. It also occasionally happens, that, owing to unknown causes, morsels of the true root will generate what are called adventitious buds; and hence we do occasionally see the root employed for propagation, as in Cydonia japonica, Anemone japonica, &c., but these are exceptional cases, and do not affect the general rule.

Since, however, there are many such cases, the propagator will do well to try roots whenever a plant refuses to strike by ordinary methods. Where unexpected difficulty is found to exist, the best way of proceeding is to place the cuttings of roots *on* damp sand, pressed half way into it, covered close with a bell-glass, exposed to moderate light, and kept at a temperature of from 60° to 65°. There is every reason to believe that moderate light contributes greatly to the excitement of vital action, and consequently to the formation of buds.

Monsieur Neumann in his very useful treatise on propagation gives several examples of root-striking, from among which the following may be selected. Dais cotinifolia propagates readily by its roots cut into

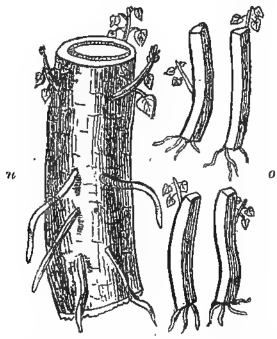

Fig. XL.—Root-cuttings of Paulownia imperialis.

pieces and laid on earth in a hothouse, although its branches strike most unwillingly. In like manner, in the case of Paulownia imperialis, portions of the roots from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch in diameter, and from 1 to $2\frac{1}{5}$ inch long, root well. The month of March is the most favourable time for striking these cuttings; for in February they often rot. The

shoots of this plant, struck from root cuttings, come out round the root as is seen in Fig. XL., *n*; this gives the means of splitting the roots into several pieces, which, separately, strike as well as an entire root, Fig. XL., *o*. In Maclura aurantiaca, Fig. XLI., roots are formed between the wood

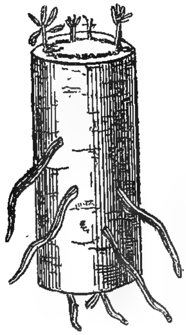

Fig. XLI.—Root-cutting of Maclura aurantiaca.

and the bark by an innumerable number of exceedingly minute bulbs, which turn green and produce buds. Cuttings of this plant strike easily in the open air. In Cydonia japonica, if we cut the roots the size of a pen into pieces 2 or 2½ inches long, and plant them upright, we shall have the same year as many plants as there were pieces planted. These cuttings should be made in the open air, along a border or strip of peat, without any other covering than the soil where they are to grow. If we plant them vertically, we should cover them very slightly with earth; and at the first watering the cut will be uncovered. If we place them horizontally, they should be covered with earth about $\frac{1}{16}$ of an inch deep. This last method succeeds equally well, but it is less certain than the first. Mons. Neumann's experience has also showed that even Conifers may be struck from pieces of the root, concerning which he makes the following statement. During six years he had many times tried to strike an Araucaria from cuttings of the roots, but without success; at last, on the 10th May, 1844, he perceived that the cuttings of the roots of Araucaria Cunninghami, ¾ inch in diameter, and about 2¾ to 3 inches long, planted in October, 1843, were sending forth shoots. He attributes his failure, up to this time, to the presence of the glasses with which he covered the cuttings: the constant presence of air charged with an excess of moisture making them perish. In the first place, the pots which contained the roots were, in October, plunged into tan still gently warm; perceiving in March that the earth in the pots was decomposed, he changed it, without being able to distinguish the least sign of vegetation on the cuttings. The pots were then placed upon a bench

and exposed to a moderate temperature; in April these pots were placed upon a warm bed of tan; and it was this, doubtless, which, a month afterwards, excited vegetation. He expresses his opinion that all Conifers may be multiplied in a similar manner if root cuttings are employed in Spring. This opinion is not, however, generally entertained by others.

When the Vine grows in a very warm damp stove, its stem emits roots into the air; the same thing happens to the Maize on the lower part of its stem; and in these and all such cases, the roots are found to be emitted from buds. Hence it has been inferred that the roots of a plant are as much productions of buds as branches are, and that the stem is nothing more than a collection of such roots held together under the form of wood and bark. The present is not the place for a renewal of this discussion, for the arguments in favour of and opposed to which, the reader is referred to my *Introduction to Botany*, 3d edit. p. 309, &c. It is sufficient here to remark, that the question turns upon whether the buds and leaves actually themselves produce roots, or merely furnish the organizable matter out of which roots are formed; and that, therefore, for the purpose of horticulture, either one or the other is equally capable of explaining the facts connected with cuttings.*

As far as physiology can explain the operation of propa-

* The following curious fact, recorded by Mr. Livingstone, which seems to have escaped observation, deserves to be mentioned here;—"The Pterocarpus Marsupium, one of the most beautiful of the large trees of the East Indies, and which grows in the greatest perfection about Malacca, affording, by its elegant wide-expanding boughs, and thick-spreading pinnated leaves, a shade equally delightful with the far-famed Tamarind tree, is readily propagated by cuttings of all sizes, if planted even after the pieces have been cut for many months, notwithstanding they appear quite dry, and fit only for the fire. I have witnessed some of three, four, five, six, and seven inches in diameter, and ten or twelve feet long, come to be fine trees in a few years. While watching the transformation of the log into the tree, I have been able to trace the progress of the radicles from the buds, which began to shoot from the upper part of the stump a few days after it had been placed in the ground, and marked their progress till they reached the earth. By elevating the bark, minute fibres are seen to descend contemporaneously as the bud shoots into a branch. In a few weeks these are seen to interlace each other. In less than two years the living fibrous system is complete; in five years no vestige of its log origin can be perceived; its diameter and height are doubled, and the tree is in all respects as elegant and beautiful as if it had been produced from seed." (*Hort. Trans.*, iv. 226.)

gation by cuttings, it appears that roots are formed by the action of leaves; that branches are developed from the buds; and that the buds are maintained by the suitable aliment stored up in the stem. Everything beyond this seems to be connected with specific constitutional powers, of which science can give no explanation.

In considering what conditions are most favourable to the maintenance of a cutting in the state required, in order to enable it to become a young plant, it will be most convenient, in the first place, to examine the rationale of some one method which is known to be successful. For this purpose, the following detail, by Mr. Knight, of his mode of striking the Mulberry, is selected:—

"A considerable number of cuttings were taken from the most vigorous bearing branches of a Mulberry-tree, in the middle of November, 1812, and were immediately reduced to the length adapted to small pots, in which I proposed them ultimately to be planted, and which were between four and five inches deep. Each cutting was composed of about two parts of two-years-old wood, that is, wood of the preceding year, and about one third of yearling wood, the produce of the preceding summer; and the bottom of each was cut so much aslope, that its surface might be nearly parallel with that of the bottom of the pot in which it was to be placed.

"The cuttings were then inserted in the common ground, under a south wall, and so deeply immersed in it that one bud only remained visible above its surface, and in this situation they remained till April. At this period the buds were much swollen, and the upper ends of the cuttings appeared similar to those of branches which had been shortened in the preceding autumn, and become incapable of transmitting any portion of the ascending fluid. The bark at the lower ends had also begun to emit those processes which usually precede the production of roots. The cuttings were now removed to the pots to which they had been previously fitted, and placed in a moderate hot-bed; a single bud only of each cutting remained visible above the mould, and that being partially covered; and in this situation they vegetated with so much vigour, and

emitted roots so abundantly, that I do not think one cutting in a hundred would fail with proper attention. Some of the pots were placed round the edges of a Melon bed, which affords a very eligible situation where a few plants only are wanted." (*Horticultural Transactions*, ii. 117.) In this case success appears to have depended upon the following circumstances:—

1. The cuttings were prepared in November, at the end of the season of growth, when all the organizable matter required for the cutting was formed, and locked up in the proper places in its interior. It was not necessary, therefore, to take any means of insuring a further supply of aliment. But had it been otherwise, that is to say, if the cuttings had been prepared in the summer, in the midst of their growth, it would have been indispensable to allow a leaf or two to remain attached to the upper end of the cutting, to assist in the formation of alimentary matter.

2. Although but one eye was allowed to grow, yet the cuttings themselves were four or five inches long, and they consisted, to the extent of two-thirds, of two-years-old wood. By this means the quantity of food for the nascent branch was intended to be so great as to insure it against suffering from an inadequate supply, until it had formed roots. The importance of this has already been shown by Mr. Knight in a previous part of this book.

3. The cuttings were taken off in November, and not in the spring. This gave them time to form granulations of cellular substance at the lower or wounded end before the powers of absorption by the alburnum were aroused, and so to protect themselves against a too copious supply of aqueous matter before the growing bud could dispose of it by its leaves. This protection is afforded by the thinnest stratum of new cellular tissue, which covers the ends of the wounded vessels, and acts as a vital filter through which all the crude food must pass from the soil.

4. The lower end of the cuttings was so divided as to be parallel with the bottom of the pot, and it appears from the context, although it is not expressly so stated, that this end was to *touch* the bottom of the pot. The importance of this pre-

caution is well known; cuttings of the Lemon and Orange, which are by no means willing to strike if it is neglected, become young plants readily if it is attended to; and in all difficult cases it is had recourse too. The object of it seems to be to place the absorbent or root end of the cutting in a situation where, while it is completely drained of water, it may, nevertheless, be in the vicinity of a never-failing supply of aqueous vapour. If it were surrounded by earth, water would readily collect about it in a condensed state, and the vessels being all open in consequence of being cut through, would rise at once into the interior; but the application of the root end immediately to the earthen bottom of the pot, with which it is so cut as to be nearly parallel, necessarily prevents any such accumulation and introduction of water, unless over-watering is allowed, and this all good gardeners will take care to avoid.

M. Neumann gives the following practical advice as to the earth in which cuttings strike most readily:—"Different sorts of trees do not root equally well in all soils. There are some cuttings which can scarcely be made to succeed in saline earth, while others succeed in it very well. The soils considered the best for striking cuttings in the open air are those which are free, sandy, and soft to the touch. Tamarix elegans and T. germanica prosper in a soil rich in saltpetre; but the Gingko and Poplars cannot strike in it. Cuttings made in glass-houses generally require to be planted in earth mixed with peat in preference to any other, but varied according to the nature of the plant. Whatever composition we use, we must take care not to employ it too dry or too moist; in the first case, the earth not being able to sustain itself in a convenient manner around the cutting, the latter falls or is displaced when we wish to water it; in the second case, the earth being too compact, it hinders the formation of roots; Nature makes vain efforts, and the cutting suffers, decays, and dies, in spite of its disposition to vegetate."

Other substances are occasionally employed with some advantage as a substitute for earth, such as chopped damp moss, brick dust, charcoal dust, burnt clay, &c. The three last substances probably act in consequence of their being bad conductors of heat, powerful absorbents of gaseous matter, and in the best mechanical state for preserving the cuttings from contact with excess of moisture.

An ingenious plan of Mr. Forsyth's is intended to answer this purpose rather more perfectly. He puts a small sixty pot

(Fig. XLII. *a d*) into one of larger size, having first closed up the bottom of the former with clay (*a*); then having filled the bottom of the outer pot with crocks, he fills up the sides (*c c*) with propagating soil, in which his cuttings are so placed that their root ends rest against the sides of the inner pot; the latter is then filled with water, which passes very slowly

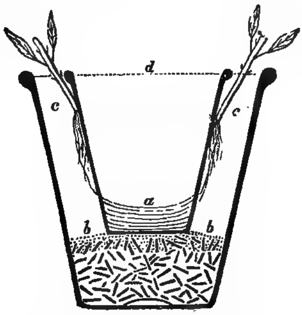

Fig. XLII.

through the sides until it reaches the cuttings. (See *Gardeners' Magazine*, vol. xi., p. 564.) In many cases, especially in striking such plants as Heaths, gardeners employ a stratum of silver sand, placed immediately over the earth in which such plants love to grow. The cuttings are inserted into the sand, but so near the earth that the roots, presently after their emission, find themselves in it, and consequently in contact with a source of food. This sand answers the same purpose as placing the root end of the cutting in contact with the pot, and is an ingenious device for doing that with small cuttings, which cannot be conveniently done otherwise except with large ones.

5. The cuttings are eventually placed in a hot-bed. This is for the purpose of giving them a stimulus at exactly that time when they are most ready to receive it. Had they been forced at first in bottom heat, the stimulus would have been applied to cuttings whose excitability had not been renovated, and the consequence would have been a development of the powers of growth so languid that they probably would not have survived the coming winter: but, the stimulus being withheld till the

cuttings were quite ready for growth, it told with the utmost possible effect.

What is demanded when cuttings of plants are to be struck, is a due adjustment of heat, light, and moisture. The first stimulates the vital processes, the second causes the formation of matter out of which roots and leaves are to be organized, the third is at once a vehicle for the food required by the cutting, and a part of it. The great difficulty is to know how to adjust these agents.

If the heat is too high, organs are formed faster than they can be solidified; if too low, decay comes on before the reproductive forces can be put in action. When light is too powerful, the fluid contents of the cutting are lost faster than they can be supplied; when too feeble, there is not a sufficiently quick formation of organizable matter to construct the new roots and leaves with. If water is deficient, the cutting is starved; if over-abundant, it rots.

It is, then, the adjustment of these forces to the peculiar nature of the cutting to be acted upon that constitutes the art of propagation. It is this which theory cannot supply, but which depends upon skill and experience. If any part of the operations of cultivation can be called empirical, it is this. And yet the operator is not without rules to guide him in this adjustment; the misfortune is, that they are too general. The softer a cutting, the quicker must be the excitement and application of the formative process. The more hard and woody a cutting, the slower will be the operation.

The great enemies of the propagator, says Mr. Neumann, are rotting and drying; for this reason cuttings are preserved in the midst of a temperature and humidity always equal, the evaporation of the soil is hindered, and the perspiration of the cuttings is prevented. Heat, light, and moisture being the agents to whose assistance we must look for success, and by whose mismanagement the hopes of the gardener are ruined, it is of the first importance to determine how each can be best and most efficiently controlled. And first of heat.

We know that plants are distributed over all parts of the habitable globe; that in neighbouring countries the species are

nearly alike, that distant countries are clothed with vegetation of entirely different kinds, and that the distinction in the vegetation is in proportion to the distance of the countries from each other. There are not, perhaps, a dozen species in Normandy that do not grow wild on this side the Channel; there are not a dozen species common to England and Bengal. Species, in fact, are in general limited by similarity of temperature, and cannot exist beyond such limits. One of the first considerations for the propagator, therefore, is what amount of heat is natural to a species during its season of growth. With less than that it is hopeless to make cuttings grow. It is only when plants strike freely that the natural amount of heat is sufficient; in general they require more. The amount of heat found in their natural climate may be enough for them to grow in; but a greater degree of excitement, by means of a higher temperature, will be demanded by them to strike root in, when cut up into the fragments called cuttings. A Willow-cutting stuck into the open ground will strike root, but it does so faster and more vigorously if placed in a hotbed. A Whitethorn cutting in the open ground will not root at all; in a warm propagating house, it will do so readily; and, to reverse the illustration, cuttings of tropical plants, which naturally enjoy a very high temperature, will perish if it is reduced, and will only put forth roots when it is raised considerably above their natural standard. Thus Mr. Neumann mentions that Nutmegs, Guaiacum, Mangoes, &c., will not succeed unless in a temperature of about 100° Fahr. That degree of heat would be fatal to greenhouse plants.

But it is not the temperature of the atmosphere that requires to be maintained above that to which plants are naturally subject: it is the soil that must be warmed. The first object is to obtain roots; those organs once formed, leaves will follow. The vital action which causes the production of roots is, in the first instance, local; roots are produced by the development of the cellular matter of the underground part; that cellular matter requires to be stimulated by unusual warmth; but the necessary stimulus cannot be communicated by a heated atmosphere: it is the warmth of the soil in which the cellular

matter lies buried that must be secured. Unusual warmth of the air would have the effect of stimulating the buds, and would cause a premature appearance of leaves, which would be anything rather than conducive to the success of a cutting. If soil were to be kept at 33°, and the air at 84°, leaves would form, but no roots would be emitted under ground, however skilful the operator; and then, unless roots were thrown out above ground, the cuttings would speedily exhaust themselves. On the other hand, if the soil were kept at 84°, and the air at 33°, leaves would certainly be formed as soon as the roots had struck out, although in a pinched and shivering condition.

A proper degree of *bottom-heat*, then, is the first point for consideration, for all other processes are subservient to that fundamental requisite; and the rule is, that it should always be higher by several degrees than that to which plants are naturally subject. Suppose, for example, that it is required to strike a cutting of some plant from Algiers, and that the mean temperature of the summer there were 70°, the safe course for the gardener to take would be, to plunge his cutting in soil warmed up to 75°.

The action of light and moisture upon cuttings is hardly inferior to that of heat. The moment light strikes a green plant it excites perspiration. Let us imagine that a cutting weighed 20 at daybreak; the uninterrupted action of light upon it during the day would perhaps reduce its weight to 5, unless it were supplied with water to replace that which the sunlight drives off: the effect of this would, of course, be to kill it. But such a result does not often happen to rooted plants, because they are able to suck fluid out of the earth as fast as the sun drives it off from their leaves, and the circulation of the plant is active enough to prevent any part from being exhausted of fluid. If it is not sufficiently active, then we have leaves withered at the end, or branches struck with dryness. But a cutting, having no roots, is unable to contend against the sun's influence, and therefore it must be shaded; for, as we cannot make it feed, we must prevent its wanting food. Thus in tropical countries we learn from Mr. Neumann that cuttings are struck in sheds shaded by straw and watered occasionally;

with us the same point is also gained by cutting off the leaves, or a part of them.

But there is this disadvantage in cutting off the access of light, that roots are formed more rapidly when cuttings are exposed to light than when they are shaded, provided they can be kept alive. It is therefore a great problem to determine how much light a cutting will endure with impunity. The power of bearing light varies from species to species, and is only to be determined by experience. One plant fades presently, because its powers of perspiration are very great, as is the case with the young shoots of most species of herbaceous and shrubby plants; but as they grow older the loss by perspiration diminishes, because their thickened skin opposes a mechanical obstacle, and they can bear more light. It would therefore seem, at first sight, that ripened cuttings must in all cases be preferable to those which are young and tender. Certainly, they are less liable to die quickly; but they are also much more unwilling to root quickly. In fact, notwithstanding the difficulty of keeping very young cuttings alive, they present the only means of striking very difficult species, such, according to Mr. Neumann, as the Cashew, the Mahogany, and the Litchi. We may lay it down as a certain rule that the power of rooting is always greatest in all cuttings when they are first pushing, provided they have light. The misfortune is, that they are so extremely perishable at that time.

Water is our aid in this case. It is true that the sun's influence can have no injurious tendency so long as the roots can drink and the system digest as fast as the surface perspires; and that the reverse is fatal. But the whole surface of a plant absorbs as well as evaporates, and the younger it is the more it absorbs. It is therefore possible to give plants water by their leaves; and if this is done with skill, the bad influence of the sun is prevented. In that case the cutting has time enough to make roots, by which its grosser food may be conveyed to it. Hence has arisen the practice of striking plants under bell-glasses, fitting tight to the soil on which they rest. Ignorant people believe that the use of a bell-glass is to keep out air, which is impracticable and useless. Bell-glasses act by keeping

in moisture. From the surface of warm damp soil water is perpetually escaping in the form of invisible vapour; if the soil is freely exposed, that vapour is dispersed as fast as it is formed; but when it is confined beneath a bell-glass the air is unchanged, and the vapour remains in a state of suspension, bathing and invigorating the whole surface of the cuttings. When this is well managed, the whole of the injurious effects of sun-light are prevented, and all the advantages of it secured.

But it is not sufficient to place cuttings under a bell-glass with a moist soil and a due supply of bottom-heat. Two other things must be considered: the one is, to preserve the external air in a uniform state; the other is, to take care that the soil is not too wet.

If the air on the outside of bell-glasses is not as warm as that beneath them, or warmer, the moisture floating in their interior will condense on the sides of the glass and run down, by which means the air that surrounds the cuttings will fluctuate as to the quantity of water it holds suspended; and if the external air is much colder than the internal, will, in fact, be dry, instead of damp. In their delicate state tender cuttings will not bear this; it is of the utmost consequence to them that all the conditions to which they are exposed, except light, should be perfectly steady.

The condition of the soil as to water is also of infinite importance. If it is wet, cuttings are apt to rot; if dry, they are sure to fade. When a cutting is placed in a wet medium, it may attract more water than it can digest; in that case its fluids will become putrid, and its solid fabric must decay. It is therefore indispensable, in all delicate operations, that the soil should be of such a nature as to be incapable of holding much water between its particles; and hence the value of silver sand, the most favourable of all the materials within a gardener's reach. Nevertheless, there are some hard-wooded plants which will not only bear an excess of water, but are the better for it, We have seen the common Ghent Azaleas struck by placing a cutting of the young wood, with a heel to it, in a bottle of water, inclosed within a large Ward's Case, none of the leaves having been removed. In such plants as the Azalea, however, it is to

be observed that the dense texture of the wood prevents the introduction of much water at a time, that the cuttings are very slender, and the leaves very large. Plants that are differently constituted can bear no such treatment. Let it be tried with a succulent plant, and the cutting would be rotten in a week. Succulent plants, indeed, will generally do best where there is no more moisture in contact with them than what the air holds suspended. When they are gummy, or milky, or resinous, it is necessary to let the end which is to be plunged in the ground become dry, so that the mouths of the veins may contract, and thus hinder the too rapid introduction of water. Mr. Neumann's mode of doing this is ingenious. When he takes off cuttings of Araucarias, Euphorbias, Vahea gummifera, and such plants, he plunges them in a pot, in damp earth, not pressed down, with their lower end upwards, so that the latter only is exposed to the air, the whole head being buried. By this means he dries the wound, without allowing any of the water of such cuttings to escape. After leaving them for 24 or 36 hours, or even more, he wipes the end, so as to remove the gummy matter that has exuded, and then puts them in again in the usual way, when they take, and the more freely according as the wound is neatly made.

In order to meet the difficulty of maintaining cuttings in an equable state with respect to both external and internal moisture, Mr. Lowe has proposed to dip their ends in COLLODION, a substance possessing great adhesive power, impenetrable by water, and impervious to air. Believing that the great difficulty attendant upon the multiplication of plants by cuttings arises from the tissues rotting by the excessive introduction of water, which the cuttings cannot decompose, or throw off as vapour, it occurred to him that if the fresh end of a cutting were smeared with collodion the injurious access of water would be cut off, and the risk much diminished. The result of his experiments confirmed his anticipations. Out of 26 collodionised cuttings of stove plants 23 grew, while only 12 out of 26 grew when the collodion was omitted. In like manner, of 33 collodionised cuttings of greenhouse plants 23 grew, but only 11 out of the same number took in the absence of the collodion. Similar

results attended other trials. It is probable that the failures in the process were ascribable to what seems to be an imperfection in his process. If, instead of merely covering the cut *end* of the cutting with collodion, he had in some cases covered the cutting itself, as far as it was plunged in the soil, he would perhaps have had still greater success. There are two kinds of cuttings which are likely to demand this treatment—the one of succulent or very *soft* plants, which absorb abundantly through their skin; and the other of *hard-wooded* plants, of little substance, which become exhausted by the drying-up of their organizable matter before roots can be formed.

It is known that plants possess some quality analogous to animal irritability, to which, for want of a better, the name of excitability has been given. In proportion to the amount of excitability in a given plant is the power which its cuttings possess of striking. The great promoter of vegetable excitability is heat. Therefore the more heat a given plant has been exposed to, within certain limits, the more readily its cuttings will strike root. This explains what seems to have puzzled Mr. Neumann. "The young wood," he says, "of trees growing in the open air will not do for cuttings; and yet, if those same trees are forced in a hothouse, their cuttings are almost sure to succeed. Physiologists have not discovered the cause of this singular phenomenon. Many attempts have been made to strike cuttings from trees growing in the open air, but without success. If, for instance, we take an old branch of Pawlovnia imperialis, in the month of March, and put it into earth, or tan, or even water, in a stove with a good temperature, its buds will soon appear, and as soon as they are long enough to make herbaceous cuttings, will strike freely. But if you take them as they form upon a tree exposed to the open air, they will not grow at all." Vegetable excitability, a most important attribute, but little thought of, is the obvious explanation of this fact.

In addition it seems desirable to add some observations upon the object of additional precautions often taken by gardeners.

Cuttings are covered by bell-glasses, whose edge is pressed into the earth. This is for the purpose of preserving a

uniform degree of humidity in the atmosphere breathed by the cuttings. It is generally necessary to leave one or more leaves upon a cutting, in order to generate organizable matter, and to assist in the formation of roots; but this is a delicate operation, for, if the leaf is allowed to suffer by excessive perspiration, the cuttings must necessarily perish. To maintain a steady saturated atmosphere around a cutting stops this danger, and hence the use of a bell-glass. A double glass has even been recommended; but, if this precaution is of any value, it must be, not because it preserves an even temperature, which is injurious rather than useful, but because it prevents condensation upon the inner bell-glass, and the consequent abstraction of atmospheric moisture, and probably acts at the same time as a kind of shade.

Notwithstanding the precaution of covering cuttings with a bell-glass, shade is also necessary, as a further security against perspiration; for light acts as a specific stimulus, whose effects are very difficult to counteract. It must, however, be employed with great caution; for, if there is not light enough, the leaves attached to the cuttings cannot form that organizable matter out of which roots are produced.

All gardeners know that the root end of a cutting should be *close below* a leaf-bud; this is to facilitate the emission of roots by the buds, which emission must necessarily take place with greater or less difficulty in proportion as their exit is facilitated or impeded by the pressure of bark on them.

A mode of overcoming some of the practical difficulties attending the propagation of plants by cuttings has been described by Prof. Delacroix, of Besançon. This gentleman states that he, some years since, conceived the idea of insuring the success of cuttings, by putting the lower end in water, and the middle in earth, a circular incision being made between the earth and water. This was not attended with all the advantages he expected, but it led to the discovery of the following plan, which he designates a simple, economical, and certain mode of propagation. His process is described in the following words:—

"My cutting is placed entirely under-ground, so as to form a subterranean curve, of which the convexity is uppermost, the very middle of the curve being on a level with the surface of the soil. At this middle point there must be a good eye, or a small shoot. In this way the whole length of the cutting is protected by earth, and the

smaller end, instead of becoming the seat of dryness, which is always more or less injurious, becomes a passage for absorption. The bud, which, under these circumstances, is the only part exposed to the air, bears, without injury, or rather with advantage, all the causes of excitement. Although I did not commence my experiments before the end of June, I have seen quite enough to satisfy me that the method may be of serious advantage. Two drills about three inches apart were drawn parallel with each other, in a kitchen garden of indifferent quality, situated on a calcareous plain near Besançon. A hundred cuttings of Apples, Pears, Plums, Apricots, Tulip-trees, Roses, &c., almost all of this year's wood, were bent and buried in the manner described, with their ends in the two drills. They were watered a few times, and at this moment every cutting, in the open air, and exposed to the full sunshine, is just as fresh as it was when planted. In most of them, the part exposed to the air (the bud) is the seat of active vegetation, especially in the Pears and Tulip-trees, the buds of which have already made some progress."

Another ready mode of dealing with cuttings, when the means of the propagator are circumscribed, is that of striking in vials of water. A correspondent of the *Gardeners' Chronicle* thus describes his practice. "I tie vial-bottles together by the necks, and hang them in the windows of our small greenhouse, having filled them with clean soft water. I then put in slips of Salvia, Calceolaria, Mimulus, Myrtle, or anything I wish to propagate of the same description of plants; in about two or three weeks, or a month, the little silver-like roots appear, and in a week or ten days I plant them in small pots well watered; they never seem to flag or mind the change, and I rarely lose a slip. Myrtles are longer in forming roots—cuttings from the same plant have varied from six weeks to twelve months: they were put in in November. A string of bottles I also hang against the back of the greenhouse, where they have plenty of light, and they do equally well, though not quite so quickly." The practice is old, and well suited to soft-wooded plants. Even some hard-wooded kinds, such as Azaleas, strike freely in this manner.

Conifers may be increased by cuttings. About the month of September, or any time when the wood is three parts ripe, procure cuttings of the current year's growth with a small portion of the old wood attached, or what is termed a heel, selecting the small terminal short-jointed shoots, which are those most likely to form leaders; for although you may strike some of the more weakly side-shoots much easier and quicker, they are afterwards of little value, as they frequently are years before they form a good leader. Having procured the cuttings fresh from the tree, which is of great consequence,—for if they are allowed to remain any considerable time before they are put in after separation from the mother plant, there is little hope of success,—prepare them by taking the bottom leaves partly off, which should

either be done with a sharp knife or scissors. When the cuttings are thus made, procure some wide-mouthed or shallow pots, and well drain them, placing over the drainage a small portion of tufty peat or moss, and over that a layer of loam about one inch thick, filling up the remainder of the pot with white sand (the loam prevents the cuttings from cankering after they are rooted, which they are apt to do when placed in sand only); then plant the cuttings from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch deep, according to their size; but the shallower they are placed the better, provided they are made secure and not allowed afterwards to get dry, and particularly if covered with a bell-glass at first; this is not absolutely necessary if the cutting-pots are put into a frame kept quite close, as an equal temperature, both for heat and moisture, is requisite at this time. Having placed the cuttings properly in the sand, give them a copious watering, and finally remove them to some cold frame, kept close and well shaded when necessary. They may remain in this situation till the end of October, when they should be removed to some cold pit for the winter, care being taken that they do not suffer from frost or damp; but they must on no account have much artificial heat. About the end of February remove the cutting-pots to a moderate hot-bed frame, and place bell-glasses over them (if not done before); the cuttings will then root readily, and many of them will be fit to pot off by the end of June, at which time those cuttings which are not rooted should be again placed in sand, and treated as before. When first potted off, the young plants should be treated like seedlings, and afterwards hardened to the open air.

Cape Heaths, which are among the more difficult plants to strike from cuttings, are treated thus:—No particular time can be specified for the operation, because the plants are in a fit state for taking off cuttings at different times; but the earlier in the season the better, although many cultivators succeed perfectly so late as the months of August and September. The plants from which the cuttings are taken must be perfectly healthy. The wood should be firm and nearly ripe; if taken when very young it is almost certain to damp off. The short lateral shoots, about an inch or an inch and a half long, should always be chosen, the leaves stripped off them to about half their length, and the ends cut across with a sharp knife; in this state they are ready for the cutting-pot. The cutting-pots should be prepared in the following manner:—Fill them about two-thirds with broken pots, and cover these with a thin stratum of turfy peat or some other substance, to prevent the sand with which the pots are filled up from choking the drainage. The silver-sand common about London is very well adapted for striking Heaths, but almost any white sand will answer the purpose. The cuttings must be inserted in the sand, not deeply, but merely deep enough to support themselves; from a quarter to half an inch is quite sufficient. They must then be well watered, which will carry down the particles of

sand round each cutting, and render them firm enough without further trouble. Bell-glasses are of great service in striking them, but not indispensable. When they are used, they must be frequently taken off and wiped dry, otherwise the moisture will probably rot the cuttings. When they are dispensed with, the cuttings should be placed in a situation which is moist and shaded, and then they will be surrounded in a great measure with the same circumstances as under a bell-glass. Very little artificial heat is necessary in striking Heaths; much is certainly injurious. A Cucumber or Melon frame nearly exhausted, or the shaded part of a cool stove, will answer the purpose early in spring; and later in the season when the sun-heat is greater a close frame slightly shaded is all that is required. The care afterwards is to shade during bright sunshine, taking means to remove the shade early in the afternoon, so as to allow the rays, which are not then strong enough to injure the cuttings, to heat the frame, and also to see that the watering is not neglected. More, perhaps, depends upon the kind of water which is used, and the regularity with which it is given, than upon anything else in the operation, if we except the selection of proper cuttings. Rain or river water is by far the best kind to use; spring-water is usually injurious. After the cuttings have struck root, they should be gradually hardened by exposure to the air before they are potted off. Small thumb-pots are the best for the first potting, and the soil used should be very sandy peat. The greatest care should be taken to preserve the young rootlets from injury, because if this is not attended to the plants will receive a sudden check at first, which is very prejudicial. These examples will teach any intelligent person how to deal with other kinds of plants.

No further precautions are taken with cuttings, nor does it at first sight appear possible to suggest any: nevertheless the enormous constitutional difference among plants is such, that, while numerous species will strike without any difficulty under almost any circumstances, with the wood ripe or half-ripe, just formed or aged, there are many others which no art has yet succeeded in converting into plants; and it is by no means uncommon to find that, out of a potful of cuttings of the same species, apparently all alike and subjected to exactly the same treatment, one will grow and the remainder fail.

It has been thought worthy of inquiry whether bell-glasses of different colours will not produce different effects upon cuttings, in consequence of their different power of transmitting light. It has been shown by Dr. Daubeny, in a very interesting paper in the *Philosophical Transactions* for 1836, page

149, that glass of different colours exercise very different effects upon the plants exposed to the rays of solar light passing through it; that both the exhalation and absorption of moisture by plants, so far as they depend upon the influence of light, are affected in the greatest degree by the most luminous rays, and that all the functions of the vegetable economy, which are owing to the presence of this agent, follow in that respect the same law. In these experiments it was ascertained that the glass employed admitted the passage of the rays of light in the following proportions:—

	Transparent.	Orange.	Red.	Blue.	Purple.	Green.
Luminous rays	7	6	4	4	3	5
Calorific rays	7	6	5	3	4	2
Chemical rays	7	4	0	6	6	3

M. Decaisne found, during some experiments to ascertain the effect of light in causing the production of colouring matter in the Madder plant, that when the lower parts of a plant were enclosed in cases glazed at the side with transparent green, red, or yellow glass, the leaves and stem of the part surrounded by red glass, became pallid, and exhibited signs of suffering in a greater degree than under the other colours, but all were affected more or less.* (*Recherches sur la Garance*, p. 23.)

Many ingenious experiments of a similar nature have been made by Mr. Hunt as has been already stated (p. 238). But we have not ground at present to believe that they possess practical value. No advantage seems to have resulted from glazing the great Palm House at Kew with green glass of a tint selected by Mr. Hunt himself; and, in short, we have every reason to conclude that the white light which is natural to plants is that which is best adapted to their constitution; nothing more being required of the gardener than to moderate or increase its intensity.

Full details respecting the experiments of Mr. Hunt will be found in the *Gardeners' Chronicle* for 1847, p. 524, and for 1848, pp. 138, 155. In the same work for 1845, p. 55, are also recorded Zantedeschi's observations upon the influence of coloured light.

* The nature of these experiments has been misapprehended in the translation, by Mr. Francis, of Meyen's *Report on Vegetable Physiology* for 1837, p. 51.

CHAPTER XI.

OF PROPAGATION BY LAYERS AND SUCKERS.

WITH regard to layers, there is little which it is necessary to say regarding them, if what has been stated respecting eyes, leaves, and cuttings, has been rightly understood and well considered. A layer is a branch bent into the earth, and half cut through at the bend, the free portion of the wound being called " a tongue." It is, in fact, a cutting only partially separated from its parent.

The object of the gardener is to induce the layer to emit roots into the earth at the tongue. With this view he twists the shoot half round, so as to injure the wood-vessels; he heads it back so that only a bud or two appears above ground; and, when much nicety is requisite, he places a handful of silver sand round the tongued part; then pressing the earth down, so as to secure the layer, he leaves it without further care. The intention of both tongueing and twisting is to prevent the return of sap from the layer into the main stem, while a small quantity is allowed to rise out of the latter into the former; the effect of this being to compel the returning sap to organize itself externally as roots, instead of passing downwards below the bark as wood. The bending back is to assist in this object, by preventing the expenditure of sap in the formation or rather completion of leaves; and the silver sand is to secure the drainage so necessary to cuttings.

In most cases, this is sufficient; but it must be obvious that the exact manner in which the layering is effected is unimportant, and that it may be varied according to circumstances. Thus, Mr. James Munro describes a successful method of

layering brittle-branched plants by simply slitting the shoot at the bend, and inserting a stone at that place (*Gardeners' Magazine*, ix. 302): and Mr Knight found that, in cases of difficult rooting, the process is facilitated by ringing the shoot just below the tongue, about midsummer, when the leaves upon the layers had acquired their full growth (*Hort. Trans.*, i. 256); by which means he prevented the return of sap further downwards than the point intended to root.

It will sometimes happen that the branch of a plant cannot be conveniently bent downwards into the earth; in such cases, the earth may be elevated to the branch by various contrivances, as is commonly practised by the Chinese. In this no other care is necessary than that required for layers, except to keep the earth surrounding the branch steadily moist.

Suckers are branches naturally thrown up by a plant from its base, when the onward current of growth of the stem is stopped. Where this occurs the onward growth of a plant is arrested, the sap is driven to find new outlets, and adventitious buds (see p. 44) are very likely to be developed; the well-known effect of cutting down a tree is an exemplification of this. Such branches, if they proceed from under ground, sometimes form roots at their base, in which case they are employed as a means of propagation; in the instance of the Pine-apple, they are made use of for the same purpose, although they do not emit roots till they are separated from the parent. Gardeners usually satisfy themselves with taking from their Pine-apple plants such suckers as are produced in consequence of the stoppage of onward growth by the formation of the fruit: but these are few in number, and not at all what the plant is capable of yielding. Instead of throwing away the "stump" of the Pine-apple, it should be placed in a damp pit, and exposed to a bottom heat of 90° or thereabouts, when every one of the latent eyes will spring forth, and a crop of young plants be the result. Mr. Alexander Forsyth, an experienced writer upon these subjects, pointed this out some years since in the *Gardeners' Magazine* (xii. 594); and there can be no doubt that his observations upon the folly of throwing away "stumps" are perfectly correct both in theory and practice.

CHAPTER XII.

OF PROPAGATION BY BUDDING AND GRAFTING.

These operations consist in causing an eye or a cutting of one plant to grow upon some other plant, so that the two, by forming an organic union, become a new and compound individual. The eye, in these cases, takes the name of bud, the cutting is called a scion, and the plant upon which they are made to grow is named the stock.

Propagation by eyes and cuttings is, therefore, the same as budding and grafting, with this important difference, that in the one case the fragments of a plant are made to strike root into the inorganic soil, and to grow " on their own bottom," as the saying is, while in the other they adhere permanently to living organic matter. In like manner, the operation of inarching, or causing the branch of one plant to remain attached to its parent, and at the same time to grow upon the branch of another tree, is analogous to layering.

The objects of these operations are manifold. Many plants, such as the Pear and the Apple, will bud or graft freely, but are difficult to strike from cuttings. Species which are naturally delicate become robust when "worked" on robust stocks; and the consequence is a more abundant production of flowers and fruit: thus the more delicate kinds of Vines produce larger and finer grapes when worked upon such vigorous sorts as the Syrian and Nice. The Double Yellow Rose, which so seldom opens its flowers, and which will not grow at all in many situations, is said to blossom abundantly, and grow freely, when worked upon the common China Rose. (*Hort. Trans.*, v. 370.) One plant may be made to bear a

different variety upon every branch, as has been seen with Pelargoniums, Fuchsias, and Cacti. (*Gard. Chron.*, 1844, 119, 213.) The peculiar qualities of some plants can only be preserved by working: this is especially the case with certain kinds of variegated Roses, which retain their gay markings when budded, but become plain if on their own bottom. (*Ib.* 492.) Fruit may be obtained from seedling plants by these processes much earlier than by any others, the quality of seedling fruit-trees may be ascertained in two or three years instead of twenty or thirty, and thus long and objectless expectation may be avoided: indeed, Mr. Knight ascertained that it is possible to transfer the blossom-buds of one plant to another, so as to obtain flowers or fruit from them immediately. He thus fixed on the Wild Rose the flower-buds of Garden Roses, "and these buds, being abundantly supplied with nutriment, afforded much finer roses than they would have done had they retained their natural situation." He repeated many similar experiments upon the Pear and Peach-tree with similar success; but in the case of the Pear, he found that if the buds were inserted earlier than the end of August or beginning of September, they became branches and not flowers.

The modes in which these operations may be practised are exceedingly various, and an abundance of methods (often fanciful) have been devised, for a complete account of which the reader is referred to Thouin's *Monographie des Greffes;* to the article "Greffe" by the same author, in the *Nouveau Cours complet d'Agriculture*, &c., edition of 1822; to Loudon's *Encyclopædia of Gardening*, part ii.; to the *Gardeners' Magazine*, vol. x. p. 305, and to future pages of the present work.

Budding consists in introducing a bud of one tree, with a portion of bark adhering to it, below the bark of another tree. In order to effect this, a longitudinal incision is made through the bark of the stock down to the wood, and is then crossed at the upper end by a similar cut (Fig. XLIII., *a*), so that the whole wound resembles the letter T. Then from the scion is pared off a bud with a portion of the bark (Fig. XLIII., *b*), and

the latter is pushed below the bark of the stock until the bud is actually upon the naked wood of the stock; the upper lips of the wound in the stock and that of the bud are made to coincide, the whole are fastened down by a ligature, and the operation is complete.

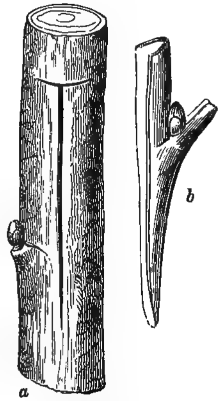

Fig. XLIII.
Shield-budding.

The ligature has usually been of bast, applied wet; but it is apt to become loose. A better material is narrow tape, or narrow adhesive straps, made as directed in a succeeding page (340). White and green worsted are also employed in preference to bast. It is also said that for delicate operations, with green parts, collodion painted over the juncture of the scion and stock, forms an effectual ligature.

By these means we gain the important end of bringing in close contact a considerable surface of young organizing matter. The organization of wood takes place on its exterior, and that of bark on its interior surface, and these are the parts which are applied to each other in the operation of budding; in addition to which the stranger bud finds itself, in its new position, as freely in communication with alimentary matter, or more so, than on its parent branch. Union takes place of the cellular faces, or horizontal system, of the stock and bark of the bud, while the latter, as soon as it begins to grow, sends down organizable matter, out of which wood, or the vertical system, is constructed. In consequence of the horizontal incision, the returning sap of the scion is arrested in its course, and accumulates a little just above the new bud, to which it is gradually supplied as it is required. Sometimes the whole of the wood of the bud below the bark is allowed to remain; and, in that case, contact between the organizing surfaces of the stock and scion does not take place, and the union of the two is much less certain: as it is, however, usually practised with tender shoots before the wood is consolidated, the contact spoken of is of less moment.

It is generally thought that, in all cases, a portion of the wood of the bud *must* be left adhering to it, or the bud will perish; because its most essential part is the young woody matter in its centre, and not the external surface, which is a mere coating of bark. But this is not the case. Buds take perfectly well without the assistance of any portion of their own wood; nor does the removal of the wood injure the eye, which is a vital portion of cellular matter firmly encased in the scales of the bud. Lymburn and other experienced practical men even advocate the total removal of the wood; and they are doubtless right, because it is only so much inactive matter interposed between the surface of the branch and the nascent tissue there, to which the vital point of the bud has to adhere. What is really essential is that the bud shall be "ripe," or fully formed; and also that it shall be sound. Immaturity or unsoundness are the usual causes of "blind buds."

Mr Lymburn even recommends, as the result of long experience, that for the usual mode of shaving a bud off a branch with some of its own wood, the operator should cut the bark all round the bud, to the exact shape and size wanted, without disturbing the wood at all. After this, if the thumb is applied to the side of the bud and gently squeezed upwards, the bud will come out as smooth as glass, in the cut, if the bark is free; and unless it is so, the budding is not likely to do well. For Cherries, Plums, Peaches, and fruit-trees in general, he considers this the best of all methods.

A practical writer in the *Gardeners' Chronicle* (1842, 604) makes the following statement as to the necessity for the bud to be ripe:—"Many buds have I inserted in early days in which the eyes have not been sufficiently swollen, and no produce has come forth; and many a bud have I inserted in the hope that the cambium would fill the vacant hole which fear told me was too large, yet which a scanty supply of buds induced me to retain, but all in vain; for though the bark adhered, the eye was lost, and many a woody bud inserted thus has become dry before it could adhere. I believe the great secret to be—taking the bud in its proper state, *i. e.*, full-formed (not too near the base of the stock, from which it will part with difficulty, nor too near the top, because insufficiently ripe), and to insert it when the receiving plant and the weather are in a favourable state to continue the elaboration of those juices necessary to form a junction. The period of year is, comparatively speaking, immaterial; I have inserted buds at all times,

and have now in my possession a plant that was worked on 21st October, ten years ago."

In the *Agricultural Journal of the Pays Bas* for October, 1824, it is recommended to reverse the usual mode of raising the bark for inserting the buds, and to make the cross cut at the bottom of the slit, instead of at the top, as is generally done in Britain. The bud is said rarely to fail of success, because it receives abundance of the descending sap, which it cannot receive when it is under the cross cut. This method is said to be practised by the orange-growers of the South of France.

Since the young bud is to be nourished at first by the leaves above it on the stock, the best place to insert it is *close beneath some leaf* in full activity; it is not, therefore, the most open and smooth part of the stock which is to be selected. For the same reason, it might appear injudicious to shorten the branch into which a bud is inserted; but if the shoot is not stopped, the rising sap will be attracted into the youngest leaves, and expended in their increase, while on the other hand, if the shoot is stopped, the sap will be forced laterally into the buds already forming on its sides, and the new bud will participate in this advantage. It is therefore, upon the whole, advantageous to cut off a part of each shoot into which a bud is introduced; the removal of a quarter of it is enough to answer the intended purpose.

As it is important that the vigour of the budded branch should be preserved for the buds which it is forming, all flowers or fruit should be removed both from it and from the twigs in its vicinity, otherwise those parts will consume the organizable matter which would be applied to the service of the new buds. Prickles, however, do no harm, and may possibly be useful, although we do not know what their use is.

Another point is the propriety of leaving a leaf upon the bud to be inserted. This question is one which practice can answer better than theory. Theory says the leaf will *injure* the bud by carrying off its fluid particles, and *assist* it by the secretions it will send down to it, and to the nascent tissue forming beneath it. Now, since the abstraction of fluid is rapid and

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they only cut them back when the inserted buds are in a good state of vegetation.

There are fruit-trees which cannot be budded thus until the leaves make their appearance, such as the Mulberry, Walnut, Chestnut, &c.; and in order to succeed well with these it is necessary to take buds from two-year-old wood, in which case the branches had better be cut off in March and preserved carefully in earth. When the vegetation of the stocks for the reception of these buds shall have become decidedly active, the branches should be washed without much rubbing, wrapped in a damp cloth, and placed from thirty to forty hours in a moist atmosphere of between 60° and 70° F., in order to expand their latent sap, so as to cause their bark to run. The buds are removed as follows:—With the blade of the grafting knife we cut the shoot obliquely (see Fig. XLV., *c*); then we place the knife about three-quarters of an inch above the eye for the purpose of raising it with a large slice of bark; to do this the more readily we make the slope towards the eye, cutting through the bark and a small portion of alburnum. The knife should preserve the same slope while passing under the eye, and continue its course till it meets the first cut. This eye should be examined by taking it lightly between the fingers of the left hand and with one of these gently bending down the portion of bark placed above the growing point; then, by means of the thumb of the right hand and the blade of the grafting knife, placed in the same hand, we can lay hold of the alburnum and remove it; but the removal should not extend beyond the growing point, which ought to be preserved entire. If from want of practice the patch of alburnum is too thick (and this we shall always know to be the case when it brings the eye along with it), we must thin the whole in order that it may separate without tearing out that essential part. Then proceed as follows: With the grafting knife make a horizontal incision, which shall embrace almost one-third of the stock, cutting through the bark as far as the alburnum; another incision to the same depth should be made downwards and perpendicular to the first, the two representing the letter T; then slightly raise the bark at the circular cut, taking care that in doing so the handle of the budding knife does not bruise the *cambium*.

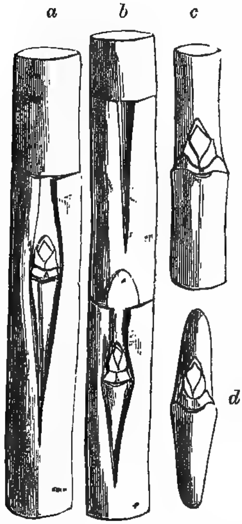

Fig. XLV.—Buds with pushing eyes.

Thus prepared, as seen at Fig. XLV. *d*, the bud should be pushed

under the two lips of the cut, only partially opened previously, for it is by gently pushing in the bud with the thin part of the handle of the budding knife that the opening is sufficiently effected. When the bud is perfectly fitted at the base and placed as is represented, the portion of its bark which extends above the transverse line is cut off. This operation is represented by Fig. XLV. *b*. The two lips are then brought together and fixed over the bark of the bud by means of woollen or thick cotton thread, the length of this thread being proportioned to the thickness of the stock; two-thirds of the length should be kept in reserve in the right hand, the rest in the left. Thus divided, we place it opposite the bud and draw the two ends with a moderate force, crossing them above the bud and as close to it as possible without crushing it. Two or three other turns should be made in the same manner, winding the thread continually in the same direction, and finally securing it by a half-knot. When the stocks are strong it is as well to inspect the ligatures soon and to loosen them occasionally, in order to preserve the buds from strangulation. When the bud shall have completely taken the ligature may be removed, and we then cut off all shoots springing from the stock below the bud in order that the latter may appropriate the whole of the sap.

Dormant Eyes (*à œil dormant*).—Some time before performing this operation select the place on each stock which the bud is to occupy, and remove all shoots likely to deprive it of the free contact of air. If this precaution has been neglected, then the removal of the shoots should only take place at the moment when the bud is inserted, and even then there is a chance of failure. It has long been known that this mode of budding has great advantages over others, seeing that if the buds do not succeed the stocks are but little deteriorated by the proceeding; there is frequently an opportunity of repeating the operation ten or twelve days after the first, and, as a last resource, these stocks may be grafted over again in the following season. Experienced budders judge that it is time to perform the operation when three-fourths at least of the shoots of each stock have ceased to push; in this state the bark is mature, and yet can be easily detached from the woody substance which it covers, and the sap being more stationary, we no longer dread impetuous superabundance, which is always detrimental to the buds, frequently causing them to perish from plethora, or as we say to be drowned in sap. If, however, circumstances render it necessary to bud before this excessive flow of sap is over, which is indicated by the great number of shoots still forming, it is proper to cut back all the soft tops as soon as the bud is inserted. The ligature should be removed at the fall of the leaf, in order to avoid the stagnation of moisture about the bud. The heads of the stocks thus budded should be cut back in the following spring, for we must not be in too much haste, especially with delicate species having viscid sap. Cut back the stock to within an eighth of an

inch above the bud and sloping. In extensive operations the cutting back is done roughly at three or four inches above the bud, in order that the stump may serve as a support to the shoot produced by the bud, which for a time is fastened to it.

Shield-budding without alburnum (Fig. XLVI. *b.—Greffe en écusson dénué de bois*).—This is employed for propagating delicate trees and shrubs with slender wood and thin tender bark. The form of the shield is usually traced with the blade of the grafting knife, cutting completely through the bark; then having removed a portion of that which is above it, we press the shield between the fingers, and with a jerk detach it from its position along with the small fleshy growing point; if by mischance the latter is bruised or remains attached to the alburnum, the shield must be destroyed and another substituted. To avoid this inconvenience we employ a fine wire, as indicated at *b*, which, by pulling the two ends, is made to glide along the alburnum, easily detaching the shield with the growing point adhering to it.

Inverted ⊥ budding (Fig. XLVI. *a*).—Prepare a shield the point of which shall be above the eye—see *a*. Raise this shield by means of a wire, as above explained; make in the stock an opening by the cut indicated in the figure, and there insert the shield by introducing its point at the base of the opening; unite the parts, and secure the whole by a ligature, which should commence below the eye. This mode of budding is preferable to all others for propagating the finest varieties of Oranges and Olives, and all tender trees with viscid sap.

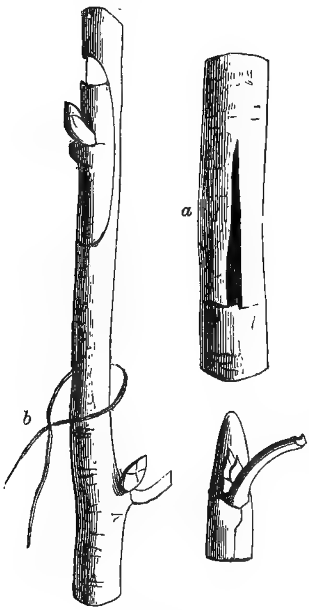

Fig. XLVI.

Square Shield-budding — (Fig. XLVII. *c*. *Greffe en écusson, dite emporte pièce*).—From a strong tree, remove a square patch; raise from a strong branch another piece of the same shape, but larger, and furnished with an eye; fit this piece into the place of the first; and cover it with a piece of paper, pierced with a hole for the eye, securing the whole by a ligature. This is to be employed for trees with very thick bark and large eyes; such as Walnut and Mulberry-trees. It may be performed in spring, for budding with the pushing eye; or even with the dormant eye, in August, or later.

Flute-budding (*Greffe en tuyau dite en flûte*).—Of this, which is an ancient practice, two modifications only deserve mention—the first, with the pushing eye; the second, with the dormant-eye.

a. *Flute-budding with Shooting Eyes* (Fig. XLVII. *a*).—In spring,

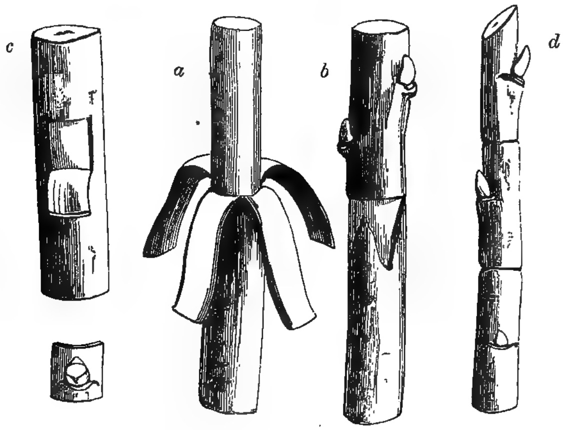

Fig. XLVII.

when the bark of both stock and scions runs freely, the latter are cut off, and immediately wrapped in a moist cloth, in which they may be kept four days; but it is better not to cut them till a short time before the buds are to be taken off, after which the operation must be as expeditious as possible. Before attempting to remove the bark of either the scion or stock, cut off all angular parts; then at the summit of the latter make three or four longitudinal incisions in the bark, in order to separate it easily, as is represented at letter *a*. Then, from the scions select one a little stronger than the stock, and trace on it two circles which mark the length of the tube of bark, on which there should be at least one good eye, or two when they are not wide apart; see letter *b*. The scion should then be held in the hand for a minute or two, in order to warm and expand the bark, which will then be more easily detached from the alburnum by a smart twist. The flute or tube thus separated, should be immediately transferred to the naked part of the stock; but this being smaller, the bark is stripped down till the flute in descending fits tight, all its interior surface being in contact with the alburnum of the stock. This being effected, we sometimes bring up the strips of bark over the flute to protect it from the contact of air. More generally, the loose bark is cut off; but in this case it is necessary to cut the naked part of the stock above the flute into thin strips, so as to form a fringe for protecting the parts operated upon from air and water.

b. *Flute-budding with Dormant Eyes* (Fig. XLVII. *d*).—This is practised exclusively, during the month of August, with wood produced by the spring sap. The part from which the buds are taken ought to be as thick as possible; and as soon as it is separated from the parent tree, the leaves are removed, a small part of their stalks being alone preserved; immediately after which the buds are raised. The operation differs from the preceding in nothing except slitting the bark longitudinally, laying the tube open through its whole length, and thus rendering it easy to extract all adherent parts. This done, it is applied to the stock, of which we preserve the top; the lower part of the stock should be as thick as the tube itself. From the stock we remove a tube of the same dimensions as the other, by which it is immediately replaced, care being taken that the edges everywhere coincide; it is kept in its place by a ligature, which had better be removed before winter. The stock is not headed down till spring, in order that the bud may partake of the general growth. This mode is difficult to perform, and is only used for propagating delicate trees, whose bark will not readily run in spring, and when a supply of descending sap is absolutely necessary for success.

27 In GRAFTING no attempt is made to apply the inner surface of the bark of a scion to the outer surface of the wood of the stock; but the contact is effected by the wood of the two, and their bark only joins at the edges. Whip-grafting (Fig. XLVIII.) is the commonest kind; it is performed by heading down a stock, then paring one side of it bare for the space of an inch or so, and cutting down obliquely at the upper end of the pared part, towards the pith; the scion is bevelled obliquely to a length corresponding with the pared surface of the stock, and an incision is made into it near the upper end of the wound obliquely upwards, so as to form a "tongue," which is forced into the corresponding wound in the stock; care is then taken that the bark of the scion is exactly adjusted to that of the stock, and the two are bound firmly together.

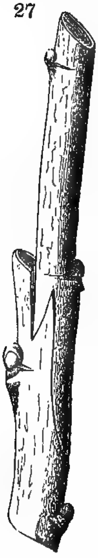

Fig. XLVIII.

Here the mere contact of the two enables the sap flowing upwards through the stock to sustain the life of the scion until the latter can develop its buds; at the same time the cellular system of the parts in

contact unites by granulations; and, when the wood forms, it passes through the cellular deposit, and holds the whole together. The use of "tongueing" is merely to steady the scion, and to prevent its slipping. The advantage of this mode of grafting is, the quickness with which it may be performed; the disadvantage is, that the surfaces applied to each other are much smaller than can be secured by other means. It is, however, a great improvement upon the old crown-grafting, still employed in the practice of some Continental gardeners, but expelled from Great Britain; which consists of nothing more than heading down a stock with an exactly horizontal cut, and splitting it through the middle, into which is forced the end of a scion cut into the form of a wedge; when the whole are bound together. In this method the split in the stock can hardly be made to heal without great care, if at all; the union between the edges of the scion and those of the stock is often imperfect, because the bark of the former necessarily lies upon the wood of the latter, except just at the sides; and, from the difficulty of bringing the two barks sufficiently in contact, neither the ascending nor descending currents of sap are able freely to intermingle. This plan, much improved by cutting out the stock into the form of a wedge, instead of splitting it, may, however, be advantageously employed for such plants as Cactaceæ, the parts of which, owing to their succulence, and consisting chiefly of cellular matter, readily form a union with each other.

The method employed in grafting Cacti is thus described, in the *Gardeners' Chronicle*, by Mr. John Green, one of the most skilful growers of ornamental plants that this country has known:—"I grow for stocks, Pereskia aculeata, Cereus hexagonus, and Cereus speciosissimus; I prefer the latter, on account of its hardy, lasting, and robust habit. I grow the stocks freely till they attain the height that I want them. Some I grow with five or six stems, from one to five feet high; others I grow with one stem, from one to four feet; the short stems I engraft at the top with the Epiphyllum speciosum and Ackermanni, the tall single stems with E. truncatum, and some from the surface of the pot to the top, all of which is of course according to individual fancy; E. truncatum should always be engrafted high, without which, from its drooping habit, the greater part of the beauty of the

bloom is lost. The grafts that I find to succeed the best, are young-growing shoots, about one and a half or two inches long. I pare off the outer skin or bark for about half-an-inch at the base of the graft, and cut what is intended to be inserted into the stock in the shape of a wedge; I then make an incision in the angles or top of the stock, with a pointed stick made the same shape as the scion. When the grafts are first put in, to prevent their slipping out, I pass through each a small wooden peg or the spine of a thorn; I then cover each with a small piece of moss, and place them in a shady damp house, and syringe them over the tops occasionally in the evening; they will all adhere to the stocks in ten days or a fortnight, and make good plants by winter. By engrafting the finest kinds of Cacti on the stocks that I recommend above, noble specimens can be grown in a few years from one to ten feet high if required; and the size and colour of the blooms are much superior to what they ever produce when grown on their own roots. E. truncatum by the above treatment becomes quite a hardy greenhouse plant, and will bloom three months later than it does when grown in the stove on its own roots in the usual way."

Mr. Henry Ford, another successful grower, gives the following detailed account of his practice:—"Last year, having several plants of Pereskia aculeata, from eight to ten feet high, which had previously been grafted at the top with Cereus flagelliformis, I inserted at various heights upon the latter grafts of different kinds of Epiphyllum, such as Ackermanni and truncatum, with Cereus speciosus and C. triumphans. The beauty in June last of a plant of this kind which had been grafted in the previous autumn I cannot describe. In grafting them, I make, with the point of the knife, an incision upwards, into which I insert small grafts, pared a little on both sides, of the kinds required. A small piece of matting is bound round the wounded stem, to keep the grafts tight until they have taken hold, which generally is the case in three weeks' time; the bast is then untied. Where room is no object, I think it preferable to graft E. truncatum upon specimens by itself, as it flowers in the autumn, whereas the other kinds bloom in the spring and summer. The pendulous habit of Cereus flagelliformis allows of its being trained in any form, according to the fancy of the owner. I have grafted Cacti at all seasons of the year, but I find that the best time is from the end of September until November; probably owing to the plants being in a more dormant state. I apply no fire to the house during this period, unless to dry up damp or exclude frost. One specimen of Pereskia aculeata, nine feet high, which was grafted two years ago with E. truncatum, the grafts being inserted three inches apart, along the whole height of the stem, and alternately on each side, has now the appearance of a pillar, and in about six weeks' time will be covered with many hundred flowers. It is advisable in grafting these plants

to insert the scion upside down, especially if worked upon the main stem; in which case I remove a small piece of the bark from the stock, and fit a thin piece of the desired kind upon it. If this is bound up so

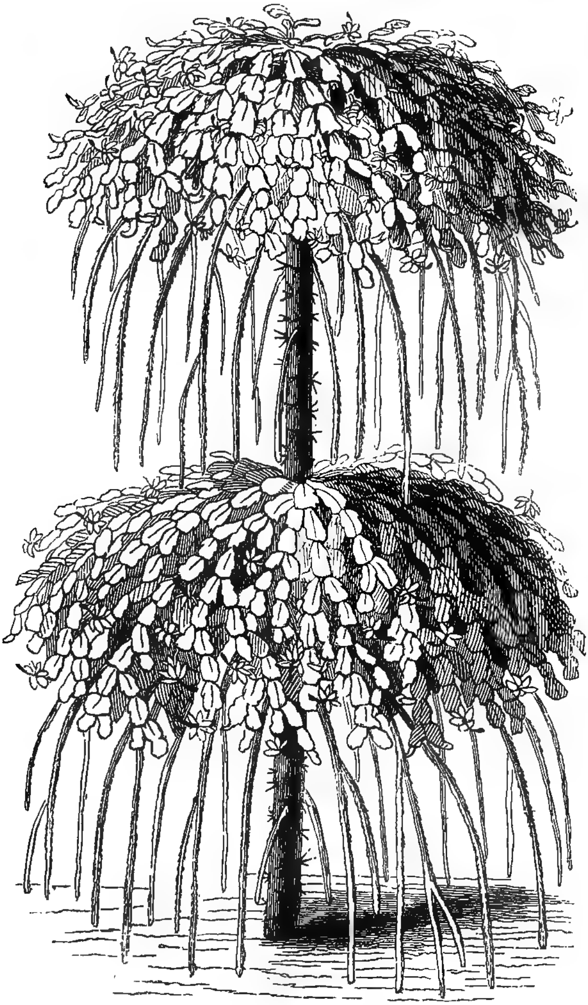

Fig. XLIX.

as to prevent air from entering between the parts, it will take quite as well as if grafted in the usual way. Where this operation is performed upon spurs, the latter should be trained downwards previously to

being grafted, otherwise the grafts, especially those with fleshy leaves, are apt to break off when they attain to any size. I have also grafted E. truncatum upon a stock of Cactus braziliensis, which makes an excellent standard, as from its robust habit it does not require any support. E. truncatum succeeds better if suspended, with a ball of earth about its roots, in a wire basket filled with moss, than when grown in a pot."

The brilliant effect produced by plants treated in this manner may be judged of from the accompanying sketch (Fig. XLIX.) of a specimen growing in the year 1847, in the garden of Mrs. Huskisson of Eartham, where it had been made by Mr. Webster, her Gardener.

A far better method than whip-grafting, but more tedious, is saddle-grafting, in which the stock is pared obliquely on both sides, till it becomes an inverted wedge, and the scion is slit up the centre, after which its sides are pared down till they fit the sides of the stock. In this method the greatest possible quantity of cellular surface is brought into contact, and the parts are mutually so adjusted, that the ascending sap is freely received from the stock by the scion, while, at the same time, the descending sap can flow freely from the scion into the stock. Mr. Knight, in describing this mode of operating, has the following observations:—

"The graft first begins its efforts to unite itself to the stock just at the period when the formation of a new internal layer of bark commences in the spring; and the fluid which generates this layer of bark, and which also feeds the inserted graft, radiates in every direction from the vicinity of the medulla to the external surface of the alburnum. The graft is, of course, most advantageously placed when it presents the largest surface to receive such fluid, and when the fluid itself is made to deviate least from its natural course. This takes place most efficiently when (as in this saddle-grafting) a graft of nearly equal size with the stock is divided at its base and made to stand astride the stock, and when the two divisions of the graft are pared extremely thin, at and near their lower extremities, so that they may be brought into close contact with the stock (from which but little bark or wood should be pared off) by the ligature." (*Hort. Trans.*, v. 147.) To execute saddle-grafting properly, the scion and stock should be of equal size; and

where that cannot be, a second method, in which the scion may be much smaller than the stock, has been described by the same great gardener. This (Fig. L.) is practised upon small stocks almost exclusively in Herefordshire; but it is

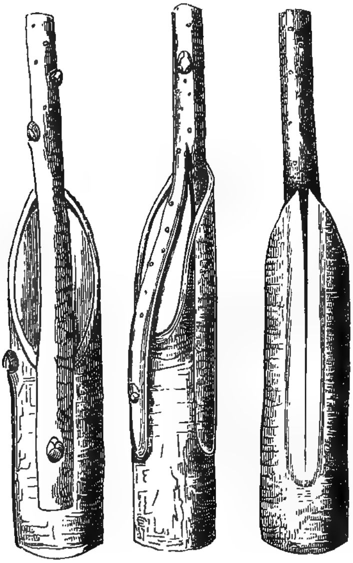

Fig. L.

never attempted till the usual season of grafting is past, and till the bark is readily detached from the alburnum. The head of the stock is then taken off, by a single stroke of the knife, obliquely, so that the incision commences about the width of the diameter of the stock below the point where the medulla appears in the section, and ends as much above it, upon the opposite side. The scion, or graft, which should not exceed in diameter half that of the stock, is then to be divided longitudinally, about two inches upwards from its lower end, into two unequal divisions, by passing the knife upwards, just in contact with one side of the medulla. The stronger division of the graft is then to be pared thin at its lower extremity, and introduced, as in crown-grafting, between the bark and wood of the stock; and the more slender division is fitted to the stock upon the opposite side. The graft, con-

sequently, stands astride the stock, to which it attaches itself firmly upon each side, and which it covers completely in a single season. Grafts of the Apple and Pear rarely ever fail in this method of grafting, which may be practised with equal success with young wood in July, as soon as it has become moderately firm and mature.

What is called herbaceous grafting, depends entirely upon the same principles as common grafting. When two vigorous branches cross each other, and press together so as not to move, they will often form an organic union; if two apples press together, or if two cucumbers are forced to grow side by side in a space so small as to compel them to touch each other firmly, they also will grow together; herbaceous grafting is merely an application to practice of this power of soft and cellular parts to unite.

The theory of grafting is explained by those natural operations in which the process is performed by plants themselves, silently and unobserved; in which a leaf is grafted to leaf to form a flower, or leaf-edges to form a fruit. This process, which never misses, which is perfect in its result, and which effects such a surprising change in the whole appearance of the parts operated on, takes place when the tissues are in their earliest and most tender condition; when the substance of the plant is more pulpy than firm, and when the growing parts are compelled to press against each other in consequence of the narrow space in which they lie. It is clearly therefore the business of the grafter to execute his task also when the tissues are as young as he can work upon; and at all events before they become hardened by the process of lignification. This is really at the very moment when buds are bursting in the spring. If at that time the naked surface of two young shoots, just lengthening, were brought in contact with sufficient skill, we doubt not that the most perfect possible joint would be the immediate result. But this practice is opposed in the spring by difficulties which we do not as yet know how to surmount, and therefore recourse is had to parts much older, and yet young enough to form an adhesion; and as young tissue is continually growing in the inner bark of all branches

while young, the routine of grafting is reduced to cutting a slice off the two barks to be united, bringing their naked surfaces in contact, and binding them together till the adhesion is complete. No doubt ripe-wood grafting answers very well for many purposes, and we do not in any way question its advantages under certain circumstances. But most certainly herbaceous grafting is the more natural, is more conformable to true theory; and when it can be practised should be invariably employed. All "propagators" of plants are aware of this, and their results are not uncommonly a marvel to the uninitiated.

In order to secure success in herbaceous grafting, the scion and stock, being pared so as to fit together accurately, are firmly bound to each other, without being crushed; parts in full vegetation, and abounding in sap, are always chosen for the operation, such as the upper parts of annual shoots, near the terminal bud; perspiration is diminished by the removal of some of the leaves of both stock and scion, and by shading; and by degrees, as the union becomes secured, buds and leaves are removed from the stock, in order that all the sap possible may be impelled into the scion. This method, if well managed, succeeds completely in about thirty days, and is useful as a method of multiplying lactescent, resinous, and hard-wooded trees, which refuse to obey more common methods. Baron de Tschudy succeeded in this way in working the Melon on the Bryony (both Cucurbitaceous plants), the Artichoke on the Cardoon (both Cynaras), Tomatoes on Potatoes (both Solanums), and so on. The following account of managing Coniferæ, where herbaceous grafting is used, is taken from the *Gardeners' Magazine*, vol. ii. p. 64., and sufficiently explains the practice.

"The proper time for grafting Pines is when the young shoots have made about three quarters of their length, and are still so herbaceous as to break like a shoot of Asparagus. The shoot of the stock is then broken off about two inches under its terminating bud; the leaves are stripped off from twenty to twenty-four lines down from the extremity, leaving, however, two pairs of leaves opposite, and close to the section

of fracture, which leaves are of great importance. The shoot is then split with a very thin knife between the two pairs of leaves (Fig. LI. *a*), and to the depth of two inches. The scion is then prepared (*b*): the lower part, being stripped of its leaves to the length of two inches, is cut, and inserted in the usual manner of cleft-grafting. They may also be grafted in the lateral manner (*c*). The graft is tied with a slip of woollen, and a cap of paper is put over the whole, to protect it from the sun and rain. At the end of fifteen days this cap is removed, and the ligature at the end of a month; at that time also the two pairs of leaves (*a*), which have served as nurses, are removed. The scions of those sorts of Pines which make two growths in a season, or, as the technical phrase is, have a second sap, produce a shoot of five or six inches in the first year: but those of only one sap, as the Corsican Pine, Weymouth Pine, &c., merely ripen the wood grown before grafting, and form a strong terminating bud, which in the following year produces a shoot of fifteen inches, or two feet."

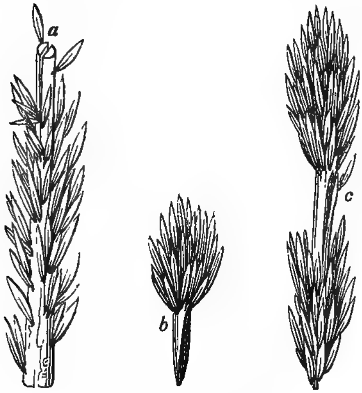

Fig. LI.—Herbaceous grafting.

With regard to INARCHING, which was probably the most ancient kind of grafting, because it is that which must take place accidentally in thickets and forests, it differs from grafting in this, that the scion is not severed from its parent, but remains attached to it until it has united to the stock, to which it is tied and fitted in various ways; the scion and stock are therefore mutually independent of each other, and the former lives upon its own resources, until the union is completed.

In practice, a portion of the branch of a scion is pared away, well down into the alburnum; a corresponding wound is made

in the branch of a stock; "tongues" are made in each wound so that they will fit into each other; and the liber and alburnum of the two being very accurately adjusted, the whole are firmly bound up; grafting clay is applied to the wound, and the plants operated upon are carefully shaded; in course of time the wounds unite, and then the scion is severed from its parent. Gardeners consider this the most certain of all the modes of grafting, but it is troublesome, and only practised in difficult cases. The circumstances most conducive to its success are, to stop the branch of both stock and scion under operation, so as to obtain an accumulation of sap, and arrest the flow of sap upwards; to moderate the motion of the fluids by shading; to head back the stock as far as the origin of the scion, as soon as the union is found to be complete; and at the same time to remove from the scion a part of its buds and leaves, so that there may not be a too rapid demand upon the stock, at a time when the line of union is still imperfectly consolidated.

One of the most happy applications of the art of inarching is that by means of which old naked branches are clothed with new wood. It is well known that if herbaceous grafting or inarching (Fig. LII.) is employed with the Pear-tree, in the month of July, the scion will have "taken" in three weeks, and will reach the length of perhaps fifteen inches before autumn. Of this the French gardeners take advantage in a very ingenious way, in order to restore to fruit-trees their lost limbs, or to complete the symmetry of form on which they so justly pride themselves. Mr. Thompson, in an account of a visit to the gardens near Paris (*Journ. Hort. Soc.* ii. 239), says that he viewed with astonishment some trees thus treated at Corbeil, near Fontainebleau. "They were fine trees, covering a wall, and trained horizontally. But they were not planted when young, and trained progressively in order to produce this regularity. On the contrary, they were planted when large and irregularly grown, having in some places a redundancy, in others a deficiency, of branches. Various means are frequently resorted to with the view of supplying branches where wanted; such as notching, budding, or side-grafting the stem; but here the desiderata were obtained by inarching the *growing extremities* of adjoining shoots to the parts of the stem whence the horizontals should proceed. Supposing the branches of a tree are trained horizontally a foot apart, with the exception of some where the buds intended to produce branches did not break, as is often the case; then a shoot, *a*, is trained up, and,

when growing in summer, a small slice is taken off near its extremity, and a corresponding extent of surface immediately below the inner bark of the stem is exposed; the two are joined together, and the point of the shoot *a* is inclined in the direction to form the branch *c*.

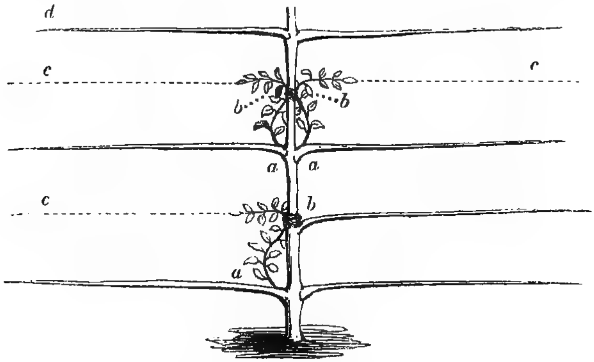

Fig. LII.—Old Pear-branches inarched with young wood.

"The most remarkable feature in the trees at Corbeil was the uniformity of vigour in the respective branches. It appeared as if the supplied branches *c c*, had been allowed to grow in connection both with the stem at *b b*, and the branch from which they originated at *a a*, till their length and thickness corresponded sufficiently with that of the branches above and below them. This is a great advantage which the mode possesses over budding or side-grafting. At the distance of a foot apart for the horizontal branches, it takes as many years to cover the wall as the latter is feet in height; for although the leading shoot may grow three or four feet in length in a season, yet by shortening it to two feet, although the branches *d d* would be produced, the buds at *b b*, to furnish the intermediate stage, most probably would not. In fact, the attempt to form two tiers of horizontals in one season is generally followed by more or less disappointment. The intermediate stage might, however, be readily supplied by the method above detailed; and a wall twelve feet high might be covered as well in six years as it otherwise would in twelve."

The advantage of this plan is obvious. The method is much more expeditious than common grafting, and is especially suited for the purposes of the amateur, who is usually in a hurry to obtain results. It must not, however, be understood that the Corbeil method is unknown in England. On the contrary, Mr. James Abraham, of Charlton Park Garden, near Cheltenham, has been in the habit of practising this method for years. He says that he has operated upon Vines, Apples, Pears, and Plums, with complete success; he has had a Vine

make upwards of thirty feet of wood in the same season as that of the operation. Mr. Abraham has produced examples of his manner of proceeding; but his method of grafting is not so good as that of the French. He employs tongue-grafting; they merely apply the two surfaces, and keep them in contact with a bandage. The disadvantage of summer tongue-grafting is that it wounds each of the branches operated upon, is tedious, and needless. The only object of a tongue is to keep a scion firmly in its place, and this is necessary where ripe-wood grafting is employed with loose scions, because the union is in that case slow, and the scions are apt to be displaced by accident; but no such risk is run in summer-grafting, and a sounder joint is made without the tongue.

A method of propagating Camellias, by putting the end or heel of a scion into a vessel of water, mentioned in the *Gardeners' Magazine*, ii. 33. is essentially the same as inarching. The water communicated to the scion through the wounded end supplies it with that food which, under natural circumstances, would be derived from the roots of the plant to which it belongs.

In the succeeding pages is given the substance of D'Albret's practical directions for the principal kinds of grafting employed in France:—

Inarching (*Greffe par approche*) is distinguished by the circumstance that both the individuals intended to be united live on their own roots, and mutually co-operate in forming a union. It is thus that we increase trees and shrubs which cannot be propagated by other modes, or at least not by any that are so well adapted for bringing plants rapidly to maturity. By some modes we can make large trees assume, in parks and forests, picturesque forms, or curved and angular timber, useful for the navy and the arts. M. Thouin has described thirty-nine modes of inarching: a few only possess general interest. Inarching is best performed when the sap is in full flow in spring. All the modes require ligatures, and some little apparatus for bringing the two portions into shape. When high stocks are destined to form curved timber, &c., take care to allow some weak shoots and branches to grow along the stems, in order to increase their thickness; without, however, robbing the parts operated upon.

Inarching Stems, for the purpose of supporting and invigorating them (see Fig. LIII.), is a modification of the *Greffe Michaux*. Select a strong tree, near which there is a slender one of the same kind, or if not, plant one, and when well established, bend it against the stem of the stock, in order to determine the most convenient place for

the union; then cut off the head of the weaker, and thin the end, as at *a;* make in the bark of the stock, *b,* two incisions, which, together, form an inverted T (⊥), from the bottom of which remove a small semicircular piece of bark (as at *c*); that above will be easily raised for introducing the extremity, *a,* the cut surface of which will rest on the alburnum, upon which it should be immediately fixed by stays and ligatures; and if the inarched tree, *b,* is large, and exposed to wind, the work is completed by driving a nail or two through the part joined. This sort of inarching may be repeatedly performed at the same time on the same individual, when there are subjects adjoining that can be adapted to it. We may also apply it to bending flexible branches to their own stems, and inserting the extremities as above described.

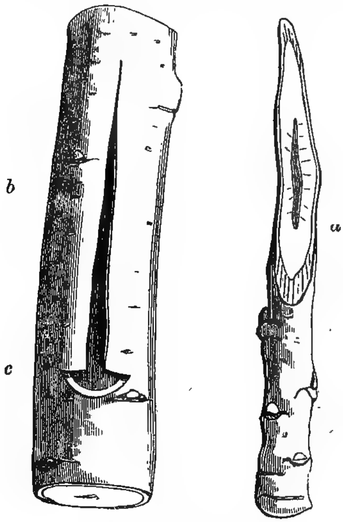

Fig. LIII.

Inarching Branches (*Greffe Monceau*), Fig. LIV.—This may be employed for the same purpose as the last, and answers better for evergreens; but whenever it is adopted, it is best to use wood one or two years old, and to take care that the portions joined are of the same age and thickness. Prepare a stock of the same size as the plant which is to join it. Make in the scion a cleft through the substance of the young wood opened from below upwards, and reaching the medullary sheath; two nearly equal parts are thus obtained, *a*; the other, *b*, is cut into a long wedge, and inserted into the cleft, so that the whole may coincide. When this mode is employed for rare plants, difficult to unite by other means, we rear the stock in a pot to the height which the plant to be inarched may require. When well taken, the inarched portion (*a*) is detached from the parent and depends entirely on the stock (*b*).

Hymen Inarching (*Greffe Hymen*), Fig. LIV.—This may be employed for the same purposes as the preceding; in forming arbours we may thus unite three or four trees. I have inarched trees in this way, under which a coach could pass in every direction. It is best practised with two subjects rather than more, and may thus be made to form an arch and posts for gateways. Prepare two trees of the same height and thickness; bring their tops together where they most readily touch; shave from each at this place an equal-sized longitudinal

slice, deepest in the middle, where it should pass through a small portion of the medullary sheath; thus prepared, the two cuts are

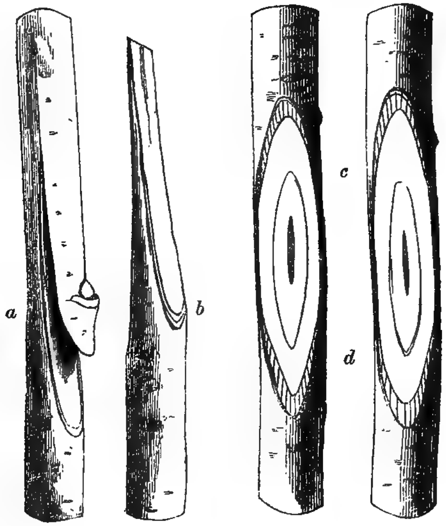

Fig. LIV.—Forms of inarching.

united, so as to mutually cover each other, and they are firmly secured by ligatures, &c. When the parts are as thick as the little finger, and they should not be thicker, a wire nail may be driven through the junction. In performing this operation care must be taken that the head of one tree exactly balances the other. In employing this for propagating rare plants, as soon as the union is well formed, the stock is headed back to a little above the union; and the sort inarched is separated from the parent as before directed.

Sylvan Inarching (*Greffe Sylvain*), Fig. LV., is best adapted for forming lozenge-shaped openings in Pear and Apple-trees trained in the form of vases, where much wood has to be supported by the branches below. If performed at their points of contact, it puts their sap in communication and unites the different parts in a remarkable manner. It may also be performed on trees with strong stems. In such cases, bend their heads towards each other so as to cross; make at this point a notch in each (as at *a*), and unite the parts, as at *b*; if they are thick, secure the joint by a strong nail, which should always be preferred to ligatures when there is much strain. The trees inarched in this way make capital hedgerows.

Inarching small Plants on large Stocks, Fig. LVI.—When one has

plants with slender shoots to inarch on strong stocks, proceed as follows:—Cut the head of the stock in a slanting direction opposite to an eye or small branch; make at the lower side of this wound a trian-

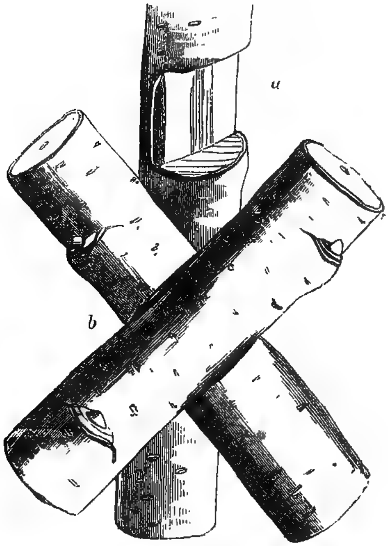

Fig. LV.

gular perpendicular cut through the bark and alburnum, as at *a*; its dimensions should always be in proportion to the size of the part to be inarched; cut the latter of an opposite form, and unite the parts. This union is sometimes difficult, on account of the difference which may exist between the thickness of the barks. When perfectly taken, the inarched portion is separated from its parent stem as usual. After this we cut off the heel, which has hitherto served as a point of attachment for the ligature, and a magazine for the sap which has aided in uniting the parts inarched. If this mode of inarching is to be performed on a large tree, of which the top has been broken by wind, we plant near it a young one, which can be inarched on the broken trunk as above explained, excepting that, instead of being sloped, the stock is cut horizontally. M. Thouin says that this mode is employed in the good climate of Caux; but in other places they prefer crown grafting, while others prefer grubbing up the trees.

Cleft Grafting.—Of this there are two principal kinds. The first comprehends those of which the stocks are thicker than the grafts, and for which ligatures may be generally dispensed with. In the second, the parts intended to be joined ought to be of an equal size, and must be

maintained in that position by a casing of paper; all should be secured with cotton thread, india rubber, or other elastic substance. Those grafts on which the leaves are preserved, should be kept in a moist

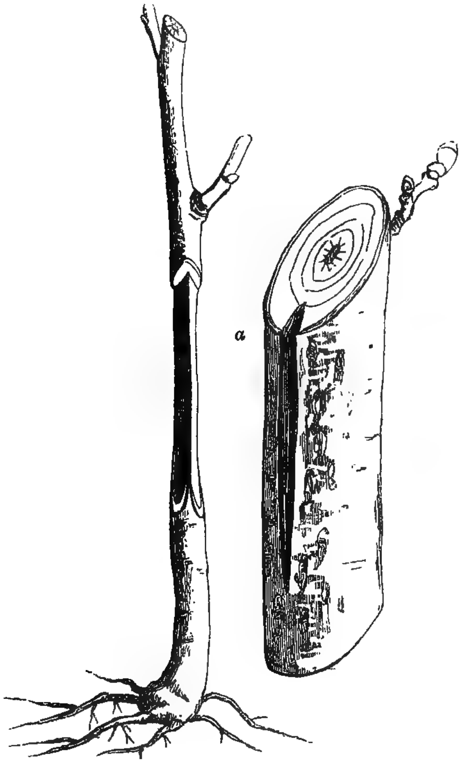

Fig. LVI.

temperature of between 60° and 75°, without air, and not exposed to bright light for a few days, according to the tenderness of their foliage. The height at which this kind of grafting ought to be performed is quite uncertain. Sometimes it is below the level of the ground on roots left undisturbed; or upon roots separated from their parent tree, which are planted in the ground after being worked. Most generally, we graft at from four to six inches above the ground, or even higher, up to as much as thirty feet. All scions intended for this sort of grafting ought to be roughly cut back in winter, before they exhibit signs of vegetation, to eight or twelve inches above the point intended to be grafted. The object of this is to retain in the stock all the sap for the benefit of the grafts when they come to be put on. The shoots which

spring from the stems of grafted trees should be checked as soon as they make their appearance, if the stock is small; but with large subjects it is different. In these some shoots *must* be left near the graft, in order to draw up the sap, which, in large trees, is sluggish, and difficult to move without them; but as soon as the sap moves freely they also should be headed back, the effect of which will immediately become visible in the rapid growth of the scions.

Cleft Grafting with one Scion, the Stock cut Sloping (Fig. LVII.).—This is one of the most usual modes of propagating many woody plants. The stock is prepared as indicated by the figure. The lower part of the scion, *a*, should be made thin by slicing off a portion from each side, and forming a small shoulder at the top of the slope, as near as possible to which there should be an eye; the side of the scion on which the bark is left should be broader and longer than the opposite side, by one-fourth, one-third, or more, according as the stocks are large or small. For the latter, the inside of the scion should be cut very thin, with a short slope; and when intended for large stocks, the same side should be left fuller, so that the scions may better resist the pressure to which they may be subjected when they are introduced into the cleft. We usually leave two eyes to the scion, but the second is often superfluous; for the one nearest the small shoulder has an immense advantage in this respect, that when the scion is introduced, as is represented at *b*, it is close to the top of the stock, and as soon as it begins to grow, it rapidly co-operates in healing over the wound of the stock. The cleft to receive the scion should be prepared as follows, by means of a strong knife, or preferably by a sort of cleaver and small mallet. The instrument should be placed across the section of the stock, and driven in so as to split the bark before the wood; always taking care that the cleft extend but little, if at all, to the bark at the lower part of the slope, on the opposite side; and on the side where the scion is to be inserted it ought to be, at first, shorter than the wedge-shaped portion of the graft. This being done, the instrument is easily knocked out by a stroke or two of the mallet, thus avoiding any kind of twisting. The wedge-shaped handle of the cleaver is next introduced slightly into the cleft, so as to keep it suffi-

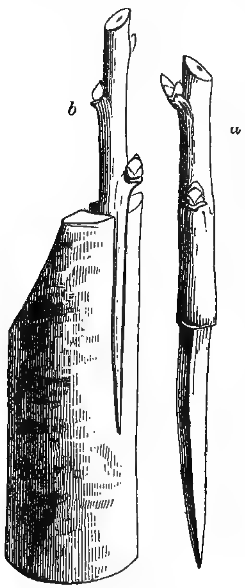

Fig. LVII.

ciently open for the introduction of all the wedge-part of the scion; this should be done in such a manner that the inner bark of the stock may correspond with that of the scion. But as we cannot always judge when this is the case, it is better that the liber of the scion should be slightly outside that of the stock rather than in contact with the young wood. The graft being properly placed, we cover the wound with a mixture of equal parts of fresh loam and cow-dung; but it is better to do over the parts with the resinous composition used for covering large wounds of trees. This composition consists of 500 grains of Burgundy pitch, mixed with 125 grains each of common black pitch, rosin, and wax, the whole well melted together, and should be applied most especially to the eye of the scion next the top of the stock, in order to secure it against insects and bad weather. When the sap is put in motion, the resin liquifies sufficiently to permit the growing shoot to pass freely through it.

Cleft Grafting with one Scion, the Stock cut Horizontally (Fig. LVIII.). This mode is much used for large tuberous roots, herbaceous stems, &c., on which we graft, successfully, herbaceous stems and others; but it is bad for woody plants in all cases where the stocks are as thick, or thicker, than the little finger, because their tranverse horizontal section is difficult to heal. For small shoots it is well adapted. When we employ this mode of grafting on herbaceous stems or branches, they ought to be cut above a leaf, or young branch, opposite to which the cleft should be made; and these small productions from the stock immediately below its section ought to be preserved almost entire until such time as the graft shall have completely taken. The young shoot is split on one side (see Fig. LVIII. *a*); and the scion is introduced. If it should happen that the latter is too large for the stock, and its fibres are not sufficiently elastic to permit the scion to be inserted, we shave one or two small parings off the cleft, so as to give it a triangular form (see Fig. LVIII. *b*); in this case we also modify the form of the scion, so that it may fill exactly the opening prepared for it.

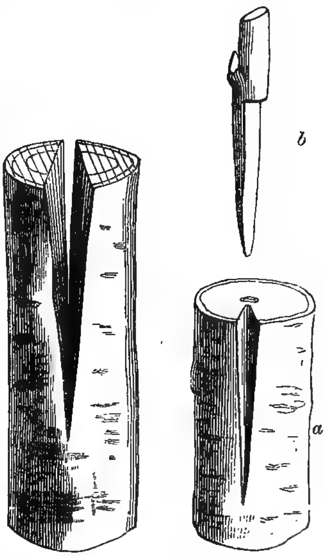

Fig. LVIII.

By this method we may propagate many hard-wooded evergreens and herbaceous stems, such as the young shoots of Pelargoniums, Melons on Gourds and Cucumbers, Tomatoes on the stems of Potatoes, Sunflowers on the Jerusalem Artichoke, &c. For the latter, shading is indispensably necessary.

Cleft Grafting with two Scions (Fig. LIX.).—The stock is cut horizontally, then split across the middle into two equal parts, or nearly so, without regarding the medullary sheath. The operations are similar to those required for Fig. LVII., excepting that the stock is cut across horizontally, and two scions are inserted. This mode is

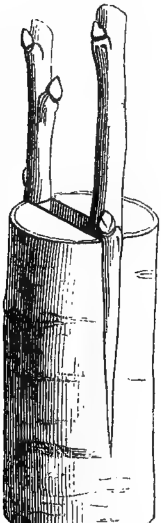

Fig. LIX.

Fig. LX.

only used for stocks that are too large for one scion, and too small to be cleft for four. In many cases we cut back one of the grafts when both take, if their growths are likely to prove injurious to each other. This, however, is not the case when the grafts are intended to form either fan-trained, or vase-shaped trees. We also use the method for grafting the strong stem of a bad Vine with a better variety; but the wood of the Vine being flexible, it is necessary to bind, securely, the parts operated upon; when the graft is above ground, and exposed to the sun, we cover the wound with resinous composition, (p. 331,) held together by a piece of cloth, in order to prevent the composition from being loosened, or thrown off by the flow of sap. Vines should be

grafted when their sap flows abundantly from small trial cuts made on their stems. [To prevent bleeding they should be in leaf.]

Cleft Grafting with Stock and Scion of equal size (Fig. LX.).—This is applicable either to herbaceous or woody parts. The scion should be cut wedge-shaped at the base; the stock should be split down the middle, and the two parts thinned, as in the figure, so that the wedge-shaped part of the scion may coincide in every point.

English Cleft Grafting, or Whip Grafting (Fig .LXI.).—This we do not generally employ, except for hard-wooded plants, with little sap and small pith. Take a straight well-grown shoot, and cut it to the length of two or three eyes; cut the base with a long slope opposite the lower eye; make a longitudinal slit in the face of the slope, so as to form a tongue. Let a counterpart be made in a stock of the same size as the scion; introduce the tongues of each into the slits prepared for them, and thus unite the whole. (See page 314, Fig. XLVIII.).

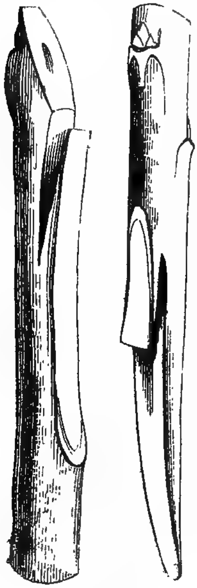

Fig. LXI.

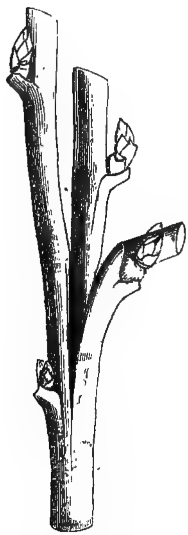

Fig. LXII.

Cleft Grafting in the Side of Shoots of the same size as the Scion (Fig. LXII).—Whatever may be the nature of the scion, its base should be cut in as lengthened a wedge-shape as circumstances will permit. The place intended for it should be previously fixed upon, and always in the fork of a small ramification of the young stem, or in the

axil of one of its leaves, or of an eye. The stem should be cut back a little above the place intended for the insertion of the scion, always taking care that the stump has one or two eyes left, or some small branchlets, leaves, &c. Make in the stock a cut somewhat slanting downwards, till it reach the pith, dividing it into two nearly equal parts. The cleft should be made by a single cut, and as quickly as possible, so that the blade of the knife may not have time to deposit iron-rust, which is always injurious to vegetation. The place being thus prepared, the scion is inserted, and must be maintained in its position, and otherwise attended to according to the practice in other cases. This mode possesses many advantages; for it is applicable to plants whose branches are of the smallest possible dimensions. I have grafted in this way Heaths and Junipers which were scarcely one-twenty-fifth of an inch in diameter. Oaks, Beeches, Walnuts, and Chestnuts, &c., either in the solid or herbaceous state, generally take well by this mode. We can easily comprehend the advantages which arise from the small stump being reserved for the purpose of drawing the sap, which, forced to collect in it, descends along the bark, and powerfully contributes to the union of the adjoining parts. During the time that the graft is taking, the sprouts that appear on the small stump should be pinched, or otherwise kept in check; after the graft has fairly taken the stump should be gradually reduced, till it entirely disappears.

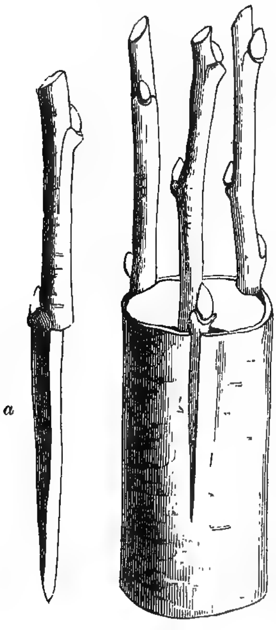

Fig. LXIII.

Crown Grafting.—The name of this sufficiently indicates the manner in which it is performed (see Fig. LXIII.). It is adapted for regrafting large old Pear and Apple-trees, but not stone fruits. The stocks should be treated in February like trees intended to be cleft-grafted. It does not make old trees young, as has been stated by many authors; but it gives them a somewhat youthful appearance by the renewal of their branches. It is an advantageous substitute for lopping in good sorts, because shoots from grafts are more proper for training than those are which spring naturally through the old bark. We know the proper time by the motion of sap in some shoots set apart, as in cleft-grafting; or we may ascertain whether the bark of the stock is able to

run, in which case we proceed as follows. Before amputating the branch or trunk, fix upon the most suitable place for grafting, and with a saw shorten back to that point, regulating and smoothing the wound with a knife; then mark out the place for each scion, about an inch and a quarter apart, always choosing those places where the bark is the most regular; but as the latter is always coarse and tough on such trees, cut it lengthwise for about an inch in length, taking care that the blade of the grafting-knife does not penetrate the alburnum. As this instrument is frequently insufficient for raising the bark so as to make way for the scion, make use of a small piece of hard wood, cut in the form of the scion, such as the latter is represented (Fig. LXIII. *a*); and in introducing the point between the bark and alburnum, we must always be careful to bruise the latter as little as possible. In order to avoid this, the instrument should not go down farther than the end of the cut made in the bark, thus effecting merely a slight entry for the scion, which, it will be observed, is cut with a long slant, and a small shoulder at the upper part of the slope, opposite to an eye. The scion thus prepared is inserted in the opening commenced for it, and gently pushed down till its shoulder rests on the top of the stock. The operation is the same with all the other scions. The whole being placed, they are secured by a split Osier firmly fixed to the stock, and brought two or three times round, and as near to the amputated part as is possible.

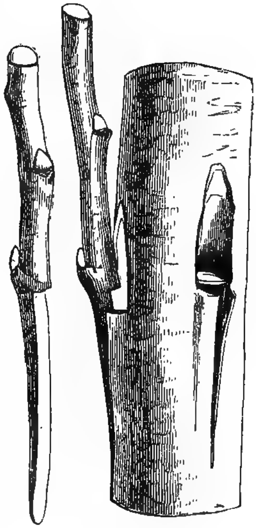

Fig. LXIV.

We employ this mode of grafting, in some extraordinary cases, without cutting off the top of the stock, when we wish to place one or more scions along a stem destitute of lateral branches. By means of a sharp chisel, three-quarters of an inch broad, make in the stock a transverse cut the whole breadth of the chisel (Fig. LXIV.), and about as deep as the thickness of a finger; above this, cut out with the same tool a somewhat triangular notch, one and a-half to two inches in length, with its depth reduced to nothing at the top, but increasing as the chisel penetrates towards the bottom of the first cut, as is represented at *a*. The object of this notch is to stop a small portion of the ascending sap, in order that it may be absorbed by the scion. In putting on the latter, place it as directed in the preceding case.

To all these may be added what has been termed *Plug-Grafting.* According to Thouin this was used by the Romans in grafting their Olives and Vines, and is mentioned by geoponical writers. The operation, which is performed in the spring, is as follows: a shoot of the previous year, having one or two eyes, is taken and shaved into a longish cylindrical form, immediately below the lower eye; a hole two or three inches deep, and as large as the graft, is then bored in the side of the stock; the graft is placed in this hole, and driven in until it fits it exactly, leaving no space between itself and the stock. If this is done, the libers will be in close contact, and the joining of the graft secure. Some years since this method was revived by a M. Vard, and submitted to the examination of a French committee, who endeavoured to ascertain whether the plan was likely to be of any importance. M. Vard said it might be used with advantage; 1st, in filling up with branches the spaces left in pyramids; 2nd, in introducing on lateral branches fruit-spurs, if they, and where they, are absent. As to the first of these uses, the committee remarked that the grafts of last spring resemble fruiting branches more than common branches, which they thought was owing to the almost horizontal position of the graft upon the stock, the ascent of the sap of which is consequently obstructed, and they decidedly preferred side-grafting, heel-grafting, or spur-grafting, whenever possible, if the object aimed at is the filling up the spaces left in pyramids. The second advantage attributed to this method the commission thought real and important. The plug-graft is easy of application, requires no ligature, is quickly inserted, and is by no means unsightly. Such advantages the committee thought likely to recommend the plan when the object is to obtain fruit-spurs from branches which have them not.

In all these methods, and in every other that could be named, it is indispensable that the cellular surfaces should be brought as much as possible into contact; for the more completely this is accomplished, the more certain is the operation to succeed. It is undoubtedly true, that, as the cellular system of a tree is diffused through its whole diameter, it is impossible to apply a scion to a stock without their cellular systems coming in contact; and, therefore, it may appear indifferent whether bark is applied to bark, and alburnum to alburnum, or whether the bark is adapted to the wood and the latter to the liber. But it is always to be remembered that each of these parts has special modifications of its own, which modifications require contact with parts

similarly modified, in order to unite readily and firmly; and also, that, although the cellular horizontal system, through which union by the first intention takes place, may be alive on all parts of the section of a branch, yet that it is in the bark, on the surface of wood, and in the space between the bark and wood, that its development is most rapid, and its tendency to growth most easily excited and maintained.

Nor are these the only circumstances to which it is necessary to attend, in order to ensure the success of these operations. It has already been seen (p. 267), that the youngest buds of the Potato are more excitable than those more completely matured; and the same appears to be true of the buds in other fruits.

"The mature bud," says Mr. Knight, "takes immediately with more certainty, under the same external circumstances: it is much less liable to perish during winter; and it possesses the valuable property of rarely or never vegetating prematurely in the summer, though it be inserted before the usual period, and in the season when the sap of the stock is most abundant. I have, in different years, removed some hundred buds of the Peach-tree from the forcing-house to luxuriant shoots upon the open wall; and I have never seen an instance in which any of such buds have broken and vegetated during the summer and autumn; but when I have had occasion to reverse this process and to insert immature buds from the open wall into the branches of trees growing in a Peach-house, many of these, and in some seasons all, have broken soon after being inserted, though at the period of their insertion the trees in the Peach-house had nearly ceased to grow." *Hort. Trans.*, iii. 136.

This property was turned to practical account by Mr. Knight in budding the Walnut. Owing to the excitability of its buds, this tree is difficult to work, because its buds exhaust all their organizable and alimentary matter before any adhesion can be formed between themselves and the stock; but by taking the small, fully matured, and little developed buds, found at the base of the annual shoots of this plant, time is given for an adhesion between them and the alburnum before they push forth, and then they *take* freely enough.

Mr. Knight described his method in the following manner:—"The fluid which the seeds of the Walnut-tree contain, when that is fully prepared to germinate in the spring, and which was deposited within it for the purpose of affording nutriment to the seminal buds, or plumule, in the preceding autumn, is sweet, as in a great many other kinds of seeds: but during germination this becomes, in the seed of the Walnut tree, bitter and acrid. Similar changes take place in the sap which is deposited, for analogous purposes, in the bark and wood of the Walnut-tree, during the germination of its buds; and I was led by the discoveries of M. Dutrochet to infer the probability, that the sap during, and subsequent to, its chemical changes, might acquire new and more extensive vital powers. I therefore resolved to suffer the buds of my grafts, and those of the stocks, to which I proposed to apply them, to unfold, and to grow during a week or ten days; then to destroy all the young shoots and foliage, and to graft at a subsequent period. A very severe frost in the morning of the 7th of May saved me the trouble of destroying the young shoots; but it deranged my experiment, by killing much of the slender annual wood, which I proposed to use for grafts; so that I found some difficulty in choosing proper grafts. The swelling of the small, and previously almost invisible, buds, within a few days enabled me to distinguish the living wood from that which had been killed by the frost, and the stocks were grafted upon the 18th of May. My grafter had more than once been previously employed by me to graft Walnut-trees in various ways, and never having in any degree succeeded, he did not seem at all pleased with the task assigned him, and very confidently foretold that every graft would die: and I subsequently found that he had insured, to some extent, the truth of his prophecy, by having applied grafts which were actually dead. The whole number employed was twenty-eight, and out of these twenty-two grew well; generally very vigorously, many producing shoots of nearly a yard long, and of very great strength; and the length of the longest shoot exceeding a yard and five inches. The grafts were attached to the young (annual) wood of stocks, which were between five and eight feet high; and in all cases they were placed to stand astride the stocks, one division being in some instances introduced between the bark and the wood; and both divisions being, in others, fitted to the wood or bark in the ordinary way. Both modes of operating were equally successful. In each of these methods of grafting it is advantageous to pare away almost all the wood of both the divisions of the grafts; and therefore the wide dimensions of the medulla in the young shoots of the Walnut-tree do not present any inconvenience to the grafter. No difficulties will henceforth, I conclude, occur in propagating varieties of Walnuts by grafting; and I am much inclined to believe, that different species and varieties of Oaks may be successfully grafted by the same mode of management."

The French work the Walnut in a variety of ways, especially preferring flute-budding (p. 308). They find it necessary, however, that the sap should be in full flow, whatever the method they employ. When the ring is properly fitted, the lips of the wound and the edges of the ring being accurately adjusted, the whole is secured with grafting wax, prepared by melting together $\frac{5}{8}$ of pitch, $\frac{1}{8}$ resin, $\frac{1}{8}$ yellow wax, $\frac{1}{8}$ tallow, with the addition of as much fine brick-dust as will give it consistence; it is used as hot as the finger can readily bear it. This sort of graft is never tied. In this way the French succeed in grafting old trees which have been headed back; but they, in such cases, operate upon the shoots which such trees throw up from the pollarded head.

Buds should either be inserted when the vegetation of a plant is languid, or growth above the place of insertion should be arrested by pinching the terminal bud; otherwise the sap, which should be directed into the bud, in order to assist in its adhesion, is conveyed to other places, and the bud perishes from starvation. For similar reasons, when a bud begins to grow, having firmly fixed itself upon the stock, the latter should be headed back nearly as far as the bud, so as to compel all the ascending current of sap to flow towards it; otherwise the buds of the stock itself will obtain that food which the stranger bud should be supplied with.

In grafting also it is always found that a union between the scion and the stock takes place most readily when the latter is headed down; but this is not the only point to attend to. The scion should always be so prepared that a bud is near the point of union between itself and the stock; because such a bud, as soon as it begins to grow, assists in the formation of wood and also in binding the two together. The scion should be more backward in its vegetation than the stock, because it will then be less excitable; otherwise its buds may begin to grow before a fitting communication is established between the stock and scion, and the latter will be exhausted by its own vigour: if, on the contrary, the stock is in a state of incipient growth, and the scion torpid, cellular granulations will have time to form and unite the wound, and the scion will become distended with sap forced into it from the stock, and thus be able to keep its buds alive when they begin to shoot

into branches. In order to assist in this part of the operation, a "heel" is sometimes in difficult cases left on a scion, and inserted into a vessel of water, until the union has taken place; or, for the same purpose, the scion is bound round with loose string or linen with one end steeped in water, so as to secure a supply of water to the scion by the capillary attraction of such a bandage. Indeed, the ordinary practice of surrounding the scion and stock at the point of contact with a mass of grafting clay is intended for the same purpose; that is to say, to prevent evaporation from the surface of the scion, and to afford a small supply of moisture; and hence, among other things, the superiority of clay over the plasters, mastics, and cements occasionally employed, which simply arrest perspiration, and can never assist in communicating aqueous food to the scion.

For the information of those who nevertheless prefer wax to clay, it may be useful to add the two following receipts for making grafting wax. 1, Bees' wax and tallow, equal parts, laid on warm with a painter's brush. 2, Four proportions, by weight, of pitch, four of resin, two of bees' wax, one of hogs' lard, and one of turpentine, melted and well mixed. When this, or some similar composition, is spread on brown paper, it forms grafting paper, as it is sometimes termed, which, being cut into slips, can be easily applied.

Another substitute for grafting clay is sheet India-rubber, cut into narrow strips or bandages, from one-half to three-quarters of an inch broad. The India-rubber is said to present all the requisites sought for in clay; it is air-tight and water-tight, and will not fall away; also it is elastic, which admits of the swelling of the scion in its growth, and it is applied with perfect ease and quickness. After wrapping the bandage round the graft and stock, as a linen bandage is applied to a cut finger, the last turn only requires securing by tying with a bit of thread or thin bast.

In some plants the scion is so slow in forming an adhesion to the stock that neither claying nor impermeable ligatures are able to keep it alive for a sufficient length of time. In that case the graft is "put on" as close as possible to the ground level and is then buried or banked up with earth till only one bud of the scion is exposed. This is called "earthing up" and is of great practical utility.

The following list includes the names of the plants to which earthing up is usually applied:—

Willows.	Mistletoe on Apples.	Ashes.
Ligustrums.	Beeches.	Vines.
Euonymus.	Acacias.	Azaleas.
Pinuses.	Elms.	Rhododendrons.
Daphnes.	Poplars.	Andromedas.
Oaks.	Chesnuts.	Kalmias.
Loniceras.	Limes.	Lilacs.
Jasminums.	Almonds.	Deutzias.
Pears on Quinces.	Cytisus.	Arbutus.
Pears on Thorns.	Sorbus.	Phillyreas.
Laurel on Cherries.	Currants.	Caraganas.
Cotoneaster on Thorns, &c.	Hollies.	Ribes, and
	Laburnums.	Amelanchiers.

Here also must be noticed certain practices, which experience shows to be important, of which theory offers no satisfactory explanation. Mr. Knight, for example, asserts that cuttings taken from the trunks of seedling old trees grow much more vigorously than those taken from the extremities of bearing branches; and it is an undoubted fact that the Beech, and other trees of a similar kind, cannot be grafted with any success, unless the scions are made of two-years-old wood; one-year old wood generally fails. Some recommend taking scions from the shoots produced at the extremities of healthy vigorous trees. And this is much insisted upon by M. De Jonghe, a very experienced practical as well as theoretical cultivator. D'Albret, however, entertains a different opinion, and considers the following experiment conclusive.

"Some years," he says, "before the first transfer of the *Ecole des Arbres Fruitiers du Jardin des Plantes*, effected in 1824, I was obliged to take grafts from more than four hundred trees, of different sorts, in a state of complete decrepitude, often covered with canker, &c. Such grafts put on healthy young stocks all grew with remarkable vigour, and the trees raised from them when from twenty to twenty-six years old, many being more than thirty-six feet high, all bore fruit in prodigious quantity, and were free from disease, when they fell under the axe in 1841."

Shoots for grafting and budding, says D'Albret, are not easily

known by the inexperienced. In general scions ought to be of medium thickness, excepting those having slender wood, in which case the thickest ought to be preferred; all should have made the greater part of their growth, so that the buds on the lower part of the shoots may be completely formed. If the parts are too tender and soft when adapted to the stock, they are apt to be rotted by the abundance of sap in the latter which ought always to be in greater flow than that of the scions.

When prepared for working, scions should not be exposed to the air, but be kept in a cool moist place till they can be budded; but under all circumstances they must be so packed as to run no risk of heating. French gardeners often place them in the hollow of an old Cucumber, and, according to D'Albret, even pack them in honey, without injury, if they have far and long to travel.

> "It has been long known that in order to preserve grafts, especially for transportation, they ought to be separated from the parent tree before they have begun to grow. In the climate of Paris, the month of February appears to be the best time for taking them off; they ought then to be placed in a northern exposure, in a horizontal position, on the ground, and covered with earth to the depth of about two inches and a half. They should remain in that position till their buds are well swelled, by which time the stock intended for their reception will be much more advanced, a necessary condition of success. If scions have to be conveyed to a distance, it is best to send them off as soon as they are taken from the tree. If the journey require only three weeks or a month, it is sufficient to tie them up in packets, putting some dry moss between them, in order to prevent their being bruised, and to insert their bases in a ball of moist clay covered with fresh moss, the whole tightly enveloped in a thin coating of straw. But if the cuttings have to be sent to a great distance, so as to be several months on the way, they should be enclosed in a box, in small parcels, all laid with their tops in the same direction, their thick ends covered with clay and fresh moss, the whole compactly fastened with laths likewise coated with moss. If for a long sea-voyage care should be taken to close the box hermetically, some holes being made in the top to prevent the shoots from becoming mouldy. I have sent grafts packed in this way to St. Petersburg, New York, &c., and they have always arrived in good condition."—*D'Albret.*

So long as it was believed that absolute wood was formed corporeally from above downwards, it was inferred that the

lower parts of a plant must be gradually encased in solid matter derived from branches, and that consequently, of necessity, the stock of a plant must be enveloped in layer above layer of the wood of the scion. It is needless to repeat the arguments employed in support of this view; they were cogent, and for a long time held to be irrefragable. The application of the theory to grafting led, among other things, to the conclusion that if a scion would take it would speedily form a sheath of wood over the stock, and thus secure itself for ever. Once, to form a good union was, therefore, looked upon as sufficient security for the permanent life of the grafted plant. It is true that cases, apparently at variance with the theory, occurred every now and then, but plausible explanations of such instances were readily found.

It is, however, now certain that although wood is formed by a descending process, yet that its descent is not in an organized state. Fluid matter, out of which it is produced, passes, indeed, from above downwards, but the formation itself is wholly local and superficial, and consequently there is no such thing as an encasement of the lower part of a tree by wood descending from above. That important fact having been once established, the union of a scion and its stock evidently becomes a case of mere adhesion, extremely powerful in some cases, feeble and readily destroyed in others. There are, therefore, two essentially different results obtained by grafting—the one permanent, the other transitory. The following example affords a new demonstration that the union between a scion and its stock is no other than that now described. (Fig. LXV.)

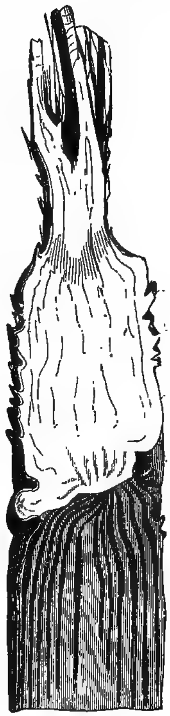

Fig. LXV.

About the beginning of September, 1853, Dr. Allan Maclean, of Colchester, an ingenious experimentalist and good physiologist, grafted a young plant of the White Silesian Beet upon a root of Red Beet, and *vice versâ*. At the time of the experiment the plants were

each about as thick as a straw. A complete junction was effected, and when, in 1854, the plant of White Beet grafted on red was taken out of the ground, its longitudinal section exhibited the appearance represented in the annexed figure. There was a slight contraction at the line of junction, much like that formed by "choking" a rocket-case; above the line of contraction the plant was absolutely white, below it it was absolutely red. Not a trace of blending the two colours could be discovered. By similar experiments on other vegetables and plants, Dr. Maclean had so far assured himself of the perfect independence of scion and stock as to acquire the belief that neither the colouring nor any of the specific characters of the one or the other would or could be altered by their union. The result of the trial wholly confirmed that view, and demonstrated that the White Beet adhered to the Red Beet by mere junction of cellular matter, that of the scion and stock holding together in the first instance, and each afterwards producing its own colouring matter in its own new cells as they formed superficially, the red cells adhering to the white cells while in the nascent state, but retaining each the peculiarity belonging to it, without any interchange of contents through the sides of the cells in contact.

This is entirely consistent with all that has been discovered by the modern physiologists who have applied themselves to a study of the nature of the individual cells of which plants consist. They have clearly shown that each cell has its own special inherent power of secretion, as indeed may be seen by any one who examines thin sections of variegated leaves or other parts. It will then be found that some cells are filled with a red colouring matter, some with yellow, some with green. In other words one cell has the power of secreting red matter, another yellow, and so on. The colours do not run together, but are contained each within the cell that produces it. Why this is so no one knows; all that we are acquainted with is the fact. In the cells of the Red Beet resides a power of forming red matter, and in those of the White Silesian Beet that of forming yellow, and this peculiarity is not affected by the one growing to the other. Red-forming cells produce their like,

and yellow-forming theirs. Thus the limit between the scion and its stock is unmistakeably traceable, and, notwithstanding the combination of the two sorts in one, each perseveringly retains that which is natural to it.

It hence becomes evident that no junction can be permanent unless the stock and scion have a great similarity, not only in every part of their structure, but also in constitution, and that the strictest consanguinity alone offers security that a grafted plant shall be as durable as each of the two individuals thus artificially joined is when left on its own roots. A temporary union may indeed be effected, but it is soon dissolved, as we everywhere see in collections where grafted varieties are brought together instead of plants "on their own bottom."

"A detached portion of a plant is not merely capable of producing the organs necessary to the formation of a perfect plant, but it has also the property of being able to blend with another plant, and lead a common life with it. On this capability depend the numerous garden operations which are known under the not very apt name of ennobling (*veredeln*, grafting). The contact of young succulent parts, which are in the course of development, is a necessary condition of this blending. Such a condition is very easily brought about in dicotyledonous plants, because in them there exists between the bark and wood that layer of young tissue in course of development called *cambium;* and there is little difficulty in so bringing together two plants, that this layer in each shall meet at some one point. But in the monocotyledons, in which the vascular bundles lie scattered through the whole stem, and no definite cambium layer exists, the conditions are far more unfavourable. It is true, according to De Candolle's account, that Baumann, of Bollwiller, succeeded in grafting *Dracæna ferrea* on *D. terminalis;* but the scion died after the first year. The experiments, indeed, of Caldrini on grafting Grasses had a more favourable result, for he succeeded in grafting even species of different genera, such as Rice upon *Panicum crus galli*. This result may be explained by the fact that in Grasses the lower part of the internodes enclosed in the leaf-sheath remains for a long time soft and succulent. A second and

indispensable condition in grafting is a great similarity of the stock and scion; they must not only be nearly allied botanically, but be much alike in the composition of their sap."

To this effect writes Mohl in that admirable treatise of his on the cells of plants,* the best work on Vegetable Physiology in any language. And this shows philosophically why it is that the operations of grafting and budding cannot be performed indifferently between any two species, although such was formerly a general belief, it being even asserted that Roses became black when grafted on Black Currants, and Oranges crimson if worked on the Pomegranate.† In reality such operations are successful in those cases only where the stock and scion are very nearly allied; and the degree of success is in proportion to the degree of affinity or constitutional resemblance. Thus, varieties of the same species unite the most freely, then species of the same genus, then genera of the same natural order; beyond which the power does not extend, unless, in the case of parasites like the Mistletoe, which grow indifferently upon totally different plants.‡ For instance, Pears work freely upon Pears, very well on Quinces, less willingly on Apples or Thorns, and not at all upon Plums or Cherries; the Cherry will take on the Laurel, or *vice versâ*; the Lilac on the Ash, the Olive on the Phillyrea, the two last cases occurring among plants of the same natural order. De Candolle even says that he has succeeded, notwithstanding the great difference in their vegetation, in working the Lilac on the Phillyrea, the Olive on the Ash, and Bignonia radicans on the Catalpa; but plants so obtained are very short-lived. For some curious particulars upon this subject, see *Physiologie Végêtale*, p. 788., &c.

* Principles of the Anatomy and Physiology of the Vegetable Cell; translated by Henfrey. 8vo. Van Voorst. 1852.

† Et steriles platani malos gessêre, valentes
Castaneæ fagos, ornusque incanuit albo
Flore pyri, glandemque sues fregêre sub ulmis.
Georg. lib. ii.

‡ Grafting the Mistletoe should be performed about the middle of May. The Apple or the Crab is the best stock, but it has succeeded on Balsam-Poplar, Willow, and many other trees. Mr. Beaton has succeeded in even working it on the Oak.

The Hon. Algernon Herbert succeeded in grafting the common Laurel on the Wild Cherry-tree; the scions, he tells us, shot vigorously, and formed a small head; but they died off in the second and third years. Deodar Cedars grafted on the Larch take freely, but soon die; and in general worked Coniferous plants are perishable and worthless, in consequence of the impossibility of finding suitable stocks for them. When, however, varieties of the Yew are inserted upon the common Yew, and Deodars on Cedars of Lebanon, the plants so obtained are permanent. When China Roses are worked upon briars they stand indifferently, and the same appears to be the case with Rhododendrons when varieties of ponticum are worked on catawbiense, or *vice versâ*, although grafted Rhododendrons are sound and permanent when *catawbiense* is inserted on *catawbiense*, *ponticum* on *ponticum*, &c.

There are two supposed cases apparently at variance with this law; both of which require explanation.

1. Columella asserts that, by a particular manner of grafting, the Olive may be made to take upon the Fig-tree, and his words have been repeated by many writers; but Thouin proved, experimentally, that no such union will take place, and that where success appears to attend Columella's operation, it is owing to the scion rooting into the soil, independently of the Fig stock (see *Mémoire sur la prétendue Greffe Columelle*), and becoming a layer.

2. Mention is made by Pliny of a tree in the garden of Lucullus, at Tivoli, which is described in his *Natural History*. On the trunk of one tree he saw branches which produced Pears, others Figs, Apples, Plums, Olives, Almonds, Grapes, &c.; but he adds, a little farther on, that this wonderful tree, which he considered as produced by the art of grafting, did not live long, and that it died some years after he first examined it. "It is probable that this tree had been formed merely by planting different species within some other. Even at the present day the gardeners of Italy, especially of Genoa, Florence, and Rome, sell plants of Jasmines, Roses, Honeysuckles, &c., all growing together from a stock of Orange, or Myrtle, or Pomegranate, on which they say they are grafted. But this is a deception, the fact being that the stock has its centre bored out, so as to be made into a hollow cylinder, through which the stems of Jasmines and other flexible plants

are easily made to pass, their roots intermingling with those of the stock; after growing for a time, the horizontal distension of the stems forces them together, and they assume all the appearances of being united. M. Thouin, who calls this "The Impostors' Graft" (*Greffe des charlatans*), tells us that he

Impostors' graft.—Fig. LXVI.

himself tried the operation with perfect success upon both a Linden and an Ash-tree a foot in diameter. He contrived to give both of them heads consisting of Plums, Hazels, wild and cultivated Services, Walnuts, Peaches, and Vines, the branches of which were thoroughly interlaced. Of one of these he gives a figure, which is here reproduced, and which perfectly illustrates the system.

In the park of the Duke of Devonshire, at Chiswick, there is a very old Cherry-tree, which has been decayed in the centre for many years. Its hollow trunk has been occupied by a common Birch-tree, so that the same stem appears to support a top composed of Birch and Cherry branches. The Cherry trunk is $7\frac{1}{2}$ feet in circumference, and 6 feet in height to the place where the branches diverge from it. To this height the Cherry-tree once completely enveloped the Birch; but of late years the diameter of the Birch has increased so much that it has burst the decaying case of Cherry wood on the north-east side, where it is partially exposed to within 18 inches of the ground. Below this the cylinder of Cherry wood is still complete. It is not surprising that the Birch should have burst the Cherry on the north-east side; for that side has usually the thinnest layers of wood, and would consequently give way the soonest to the expanding force of the Birch. The latter is now above 50 feet high, and measures 5 feet 4 inches in circumference at 6 feet from the ground, where it issues from the hollow Cherry. The portion of Cherry-tree still alive is 20 to 25 feet high. Some such case in ancient days may be well supposed to have given rise, in the first instance, to Virgilian fables, and afterwards to ingenious imitations.

From what has been now stated, it may be easily conceived that the choice of the stock on which a given plant is to be worked is by no means a matter of indifference, but that the operation may be seriously affected by the skill with which the most suitable stock is selected. If, indeed, we had no other object in view in grafting than to unite one plant to another, that object would doubtless be best attained by using the same species, and even a similar variety of the same species, for both stock and scion; the end of grafting and budding is, however, beyond this, and it may happen that the species to which a scion belongs, or the nearest variety, is the worst on which it can be worked.

One of the first objects of budding and grafting is, to multiply a given species or variety more readily than is possible by any other method. If this is the only purpose of the cultivator, that stock will obviously be the best which can be most readily procured; and hence we see, in the ordinary practice of the nurseries, the common Plum taken as a stock for Peaches and Apricots, the Wild Pear and Crab for Pears and Apples, and so on. When there is a difficulty in procuring a suitable stock, pieces of the roots of the plant to be multiplied

are often taken as a substitute, and they answer the purpose perfectly well; for the circumstance which hinders the growth of pieces of a root into young branches is merely their want of buds: if a scion is grafted upon a root, that deficiency is supplied, and the difference between the internal organization of a root and a branch is so trifling as to oppose no obstacle to the solid union of the two.

Pear-trees are sometimes grafted on roots, and it was reported by the late Mr. Wedgewood that root-grafting Vines is an invariable practice in Greece.

Knight was the first physiologist who showed the possibility of grafting scions upon roots. An account of his method of doing this was given at a very early period of the existence of the Horticultural Society (June, 1811), and he at the same time suggested the possibility of the practice being applied to grafting scarce herbaceous plants upon the roots of their commoner cogeners; an operation now commonly practised with the Dahlia, Pæony, and other plants of a similar kind; and lately a method of multiplying Combretum purpureum by similar means has been pointed out in the *Proceedings of the Horticultural Society*, i. 40.

Mr. George Gordon, a good practical gardener, gives the following advice upon this subject:—This operation is performed in two ways, either by grafting on the already established roots of young plants, or on pieces taken from the roots of older ones. The former is the easiest method for obtaining strong plants, and is best suited for plants in which a trunk is the object. In grafting upon already established roots of a young plant, first clear the soil away from the neck of the stock, and cut the head off as much below the soil as possible, at the same time observing that a sufficient length of the neck is left to receive the graft. The graft should be cut wedge-shaped, and inserted in the slit or crown-graft way (p. 330), tied tightly with a soft worsted thread, and afterwards covered with the soil, only a portion being left exposed to light and air. It greatly increases the chances of success if the worked plants are kept close, in a rather moist atmosphere for a few days, until they commence growing, but much depends upon the operation being performed at the proper time, which in most cases is just before new growth commences. In grafting on pieces of roots taken from an older plant, such pieces should be selected as are of sufficient size to receive the scion, and have some small fibres attached

to them. The roots may either be at once worked and afterwards potted or planted, or the roots may be potted a short time previous to being worked, being afterwards treated according to the nature of the plants to which they belong, whether stove, greenhouse, or hardy; but even plants belonging to the latter class are the better for a gentle moist heat for a few days to start them. In this way many plants may be increased, such as Clematis, Berberis, Roses, Combretums, Moutan Pæonies, &c., where the roots of the more common kinds are easily procured, and where suitable accommodation can be afforded; but under ordinary circumstances the chances are against the success of the system, which should only be resorted to in the case of very rare plants.

Mere propagation is, however, by no means the only object of the grafter; another and still more important one is, to secure a permanent union between the scion and stock, so that the new plant may grow as freely and as long as if it were on its own bottom under the most favourable circumstances. If this is not attended to, the hopes of the cultivator will be frustrated by the early death of his plant.

Whenever the stock and graft or bud are not perfectly well suited to each other, an enlargement always, as is well known, takes place at the line of their junction, and generally to some extent either above or below it. This is particularly observable in Peach-trees which have been budded, at any considerable height from the ground, upon Plum stocks; and it would seem to arise from the obstruction which the descending sap of the Peach-tree meets with in the bark of the Plum stock; for the effects produced, both upon the growth and produce of the tree, are similar to those which occur when the descent of sap is impeded by a ligature, or by the destruction of a circle of bark. In course of time this difference between the scion and stock puts an end to the possibility of the ascending and descending fluids passing into each other, and the death of the scion is the result. This arises in part at least from the power of horizontal growth in the stock and scion being different; and in part no doubt from irreconcileable constitutional difference between the two. For example: the Hawthorn and the Pear are so nearly allied that the latter may be easily worked upon the former; the Hawthorn is, however,

a slow-growing bush or small tree, the Pear is a large forest-tree of rapid growth; and the Pear will grow an inch in diameter while the Hawthorn is growing half an inch. Moreover all the qualities of the Pear are different from those of the Hawthorn.

The difference in the rate of growth or in other respects, if not excessive, may be taken advantage of for particular purposes. When trees grow too large for a small garden, it is desirable to dwarf them; and when they are naturally unfruitful, to render them productive; both which effects result, at the same time, from grafting them upon stocks that grow slower than themselves. Thus the Apple is dwarfed by grafting on the Paradise stock, and the Pear by the Quince. The physiological explanation of trees dwarfed by being compelled to grow upon a stock which compels their descending sap to accumulate in the branches has been already given. Instead of repeating it here, I take the following paragraph from the paper by Mr. Knight, "On the Effects of different Kinds of Stocks in Grafting," published in the *Horticultural Transactions*, ii. 199.

"The disposition in young trees to produce and nourish blossom-buds and fruit is increased by this apparent obstruction of the descending sap; and the fruit of such young trees ripens, I think, somewhat earlier that upon other young trees of the same age, which grow upon stocks of their own species; but the growth and vigour of the tree, and its power to nourish a succession of heavy crops, are diminished, apparently, by the stagnation, in the branches and stock, of a portion of that sap which, in a tree growing upon its own stem, or upon a stock of its own species, would descend to nourish and promote the extension of the roots. The practice, therefore, of grafting the Pear-tree on the Quince stock, and the Peach and Apricot on the Plum, where extensive growth and durability are wanted, is wrong; but it is eligible wherever it is wished to diminish the vigour and growth of the tree, and where its durability is not thought important.

"When," adds this great gardener, "much difficulty is found in making a tree, whether fructiferous or ornamental, of any

species or variety, produce blossoms, or in making its blossoms set when produced, success will probably be obtained in almost all cases by budding or grafting on a stock which is nearly enough allied to the graft to preserve it alive for a few years, but not permanently. The Pear-tree affords a stock of this kind to the Apple; and I have obtained a heavy crop of Apples from a graft which had been inserted in a tall Pear stock only twenty months previously, in a season when every blossom of the same variety of fruit in the orchard was destroyed by frost. The fruit thus obtained was externally perfect, and possessed all its ordinary qualities; but the cores were black and without a single seed; and every blossom would certainly have fallen abortively, if it had been growing upon its native stock. The experienced gardener will readily anticipate the fate of the graft; it perished in the following winter. The stock, in such cases as the preceding, promotes, in proportion to its length, the early bearing and early death of the graft."

It is sometimes desirable to increase the hardiness of a variety, and grafting or budding appears to produce this effect to a certain extent, not, indeed, by the stock communicating to the scion any of its own power of resisting cold, but by the stock being better suited to the soil of latitudes colder than that from which the scion comes, and consequently requiring a lower bottom-heat to arouse its excitability. Mr. Knight, indeed, denies this fact, because "the root which nature gives to each seedling plant must be well, if not best, calculated to support it;" and it is so, under the circumstances in which the species was first created; but, in gardens it is placed otherwise. Probably, in Persia, the native country of the Peach, that species, or its wild type the Almond, is the best stock for the former fruit; because the temperature of the earth is that in which it was created to grow. But in a climate like that of England, the summer temperature of whose soil is so much lower than that of Persia, the Plum, on which the Peach takes freely, is a hardy native, and suited to such soil, and its roots are aroused from their winter sleep by an amount of warmth imsufficient for the Peach. Experience, in this case, completely confirms what theory teaches: for, although there may

be a few healthy trees in this country growing upon Almond stocks, it is certain that the greater part of those which have been planted have failed; while, in the warm soil of France and Italy, it is the stock upon which the old trees have, in almost all cases, been budded.

In determining upon what kind of stock a given fruit-tree should be grafted, it is important to be aware that certain species prefer particular soils and dislike others, for reasons which are not susceptible of explanation. In the case of the common stocks employed for the propagation of the Apple, Pear, Peach, and Cherry, it was found by Mr. Dubreuil, an intelligent gardener at Rouen, that in the chalky gardens about that city neither the Plum nor the wild Cherry would succeed for stone fruit, nor the Doucin or Quince stock for Pears and Apples: but that the Crab suited the Apple, the wild Pear the cultivated Pear, the Almond the Peach, and the Mahaleb the Cherry. I formerly witnessed the result of those experiments while in progress, and I well remember the sickly state of his Peaches and Cherries grafted on Plum and Cherry stocks in the calcareous borders of the rampart gardens of Rouen, and the healthiness of the same fruit-trees in the same garden when worked upon the Almond and the Mahaleb, while the latter were unhealthy in their turn in the borders composed artificially of loam. The result of this experiment has been mentioned in the *Hort. Trans.*, iv. 566, and is as follows:—

	Loamy Soil.	Chalky.	Light.*
Apple	Doucin	Crab	Doucin.
Pear	Quince	Wild Pear	Quince.
Plum	Plum	Almond	Almond.
Cherry	Wild Cherry	Mahaleb	Wild Cherry.

Mr. Brown, of Merevale, relates the case of a Grosse Mignonne Peach which for ten years bore fruit, though rarely in abundance; at last a crop of ten dozen fruit having set and nearly ripened, it suddenly died, the stock being one mass of gum and canker. It was either a Peach or Nectarine stock, as was ascertained by a sucker which sprang up from a surface root.

* That is, with an admixture of sand and decayed vegetable matter.

As this work treats exclusively of those operations in gardening which can be explained upon known principles of vegetable physiology, all further reference to the question of stocks ought, in strictness, to be dismissed at this stage. It may be as well, however, to add that there are some well attested facts relating to the preference of particular varieties for one kind of stock rather than another, which we cannot explain, but which are so important in practice as to deserve to be studied carefully. There appears to be no doubt that, as is asserted by Mr. Knight and others (*Hort. Trans.*, ii. 215; *Gard. Mag.*, vii. 195), the Apricot succeeds better on its own species than on the Plum. Nurserymen know very well that what they call French Peaches, such as the Bourdine, Belle Chevreuse, and Double Montagne will only take on the Pear Plum, while other varieties prefer the Muscle Plum; and a variety called the Brompton suits them all equally well, making handsome trees, which are, however, uniformly short-lived.* The Lemon is also found to be a better stock for the Orange than its own varieties.

It is asserted that the tendency of the Stanwick Nectarine to crack is cured by first budding the White Magnum Bonum Plum on a Brussels stock as soon as it is strong enough for the purpose and as near the ground as possible, and afterwards by budding the Nectarine on the Magnum Bonum Plum about three feet from the ground. The same method is stated to be highly advantageous for all Peaches and Nectarines, upon the authority of a gardener at Warminster. (See *Gard. Chron.*, 1853, p. 694.)

It is not merely upon the productiveness or vigour of the scion that the stock exercises an influence; its effects have been found to extend to the quality of the fruit. This may be conceived to happen in two ways—either by the ascending sap carrying up with it into the scion a part of the secretions of the stock, or by the difference induced in the general health of a scion by the manner in which the flow of ascending and descending sap is promoted or retarded by the stock. In the Pear, the Fruit becomes higher coloured, and smaller on the Quince stock than on the wild Pear, still more so on the

* See G. Lindley's *Guide to the Orchard and Kitchen Garden*, p. 299.

Medlar; on the Mountain Ash stock the Pear bears earlier; and in these instances the ascent and descent of sap is obstructed by the Quince more than by the wild Pear, and by the Medlar more than by the Quince. Similar effects are produced in the Apple by the Paradise and Siberian Bittersweet stocks. Mr. Knight mentions such differences in the quality of his Peaches. His garden contained two trees of the Acton Scott variety, "one growing upon its native stock, the other upon a Plum stock, the soil being similar, and the aspect the same. That growing upon the Plum stock afforded fruit of a larger size, and its colour, where it was exposed to the sun, was much more red; but its pulp was more coarse, and its taste and flavour so inferior that he would have denied the identity of the variety had he not with his own hand inserted the buds from which both sprang." (*Hort. Trans.*, v. 289.)

Since the quality of fruit is thus affected by the stock, it seems allowable to infer that the goodness of cultivated fruits is deteriorated by their being uniformly worked upon stocks whose fruit is worthless; for example, the Almond or the austere Plum can only injure the Peaches they are made to bear, the Crab the Apple, and so on. On the other hand, if trees of excellent quality were used for stocks they ought to improve the fruit of the scion that is worked upon them. Some German writers, proceeding upon such reasoning as this, recommend gardeners to practise the art of "ennobling" fruit-trees by taking the best varieties for stocks instead of the worst; and they assert that, by such means, the excellence of fruit is greatly increased. Treffz is represented by Meyer, as translated in *Taylor's Magazine*, to have made known as long ago as 1803 several instances of ennobling, from which it appears that Apple-trees twice ennobled bore fruit of distinguished excellence; Currants and Gooseberries improved after one ennobling, and much more so after the operation had been repeated three and four times. An Apricot is said to have been worked on a Greengage Plum, and a Quince upon the autumn Bergamot Pear; the Apricot became as juicy as the Greengage, and far more delicate: the Quince was much more tender, and less gritty.

This is confirmed by Mr. William Billington, an experienced gardener, who mentions the following cases:—"I budded a Bergamot and a Swan's-egg Pear upon a Jargonelle on a south wall. I was surprised to find them produce fruit nearly as large again as I had ever seen the kinds bear before on any tree or aspect, and the flavour was much improved; I have seen Apples grafted upon the old English Codlin, Gennet Moil, and other Apple stocks, which are increased by burr knots, acquiring a tendency to emit roots at the joints above the ground. The effect on Apples worked upon these stocks was similar to that on the Pears just mentioned; the King of the Pippins was one, and the best judge of Apples would not have conceived it to be the same when grafted on a Burr knot as when on a Crab stock, the former being so much larger and better in every respect. I have seen the Orange Pearmain worked on the English Codlin, and besides improving in flavour and size it also became more prolific. I have budded Jargonelle and other Pears on the common Hawthorn and Mountain Ash, on which they took freely; the Pears on the Hawthorn have borne fruit three years, but the fruit is not half the common size and scarcely eatable, being harsh and gritty, and having a hard core. I have come to this conclusion —that independent of the improved size and flavour upon such stocks as the above mentioned, I think a harsh tart Apple will be much improved in flavour if grafted upon a stock of a milder sort, and a soft vapid one on a Crab, while a late austere Apple double-worked upon a luscious early Apple would be improved both in flavour and earliness. The same will apply to Pears, as the late or gritty Pears might be much improved in flavour and time of ripening by double-working on the Jargonelle and other early buttery or melting Pears. I have budded Peaches and Nectarines on the Moorpark Apricot, which greatly improved them in size and flavour. Would not, then, some of the late Peaches be much improved and come earlier into season by being worked upon Apricots?" It may be added that D'Albret regards the productiveness, fragrance, and succulence of fruits to be greatly influenced by the stock on which they are worked.

It is moreover certain that the quality of a stock is affected, in some cases at least, by the scion. Old writers on gardening assert that if you bud a yellow variegated Jasmine on a green one, the whole stock will become variegated; this is denied by Duhamel, who misunderstood the nature of the experiment, imagining it to relate to the colour of the flowers, and not of the leaves. That the colour of the leaves of a stock is affected by the scion has been demonstrated. The late Wm. Anderson, of the Physic Garden, Chelsea, budded the variegated white Jasmine upon one branch of a fine plant of the revolute

Jasmine, the leaves of which were green. The bud adhered to the bark of its stock, but never pushed. The succeeding year a slight appearance of variegation came out upon the leaves of the revolute Jasmine. The next year a workman cut out the branch which had been budded; so that the revolute Jasmine was thus apparently deprived of all influence from the variegated bud. Nevertheless, the variegation in the remainder of the plant continued to increase, and some years since the leaves and branches are all variegated, even more than the white Jasmine whose bud was originally inserted. This proves that, under some circumstances, the scion will affect the quality, although not the organization, of the stock; and if a taint producing variegation can be thus communicated, why not some other quality? It is highly probable, if not certain, that the curious *Cytisus Adami*, or purple Laburnum, which is sometimes *Cytisus Laburnum*, sometimes *C. purpureus*, sometimes a mixture of the two, is a common Laburnum tainted by a purple Cytisus in the same way as Anderson's Jasmine.

A correspondent has pointed out a passage in Scripture which bears upon this subject. It occurs in the 11th chapter of the Epistle to the Romans, and more particularly in the 24th verse:—"For if thou wert cut out of the Olive-tree, which is *wild* by nature, and were graffed contrary to nature into a good Olive-tree, how much more shall these, which be the natural branches, be graffed into their own Olive-tree!" Bloomfield says, in alluding to this chapter, "Commentators have assigned many reasons for the departure from the usual mode of grafting trees, but these are rendered nugatory by the researches of Bredenkamp, who has ascertained that in ancient times it was usual to engraft the wild into the garden tree, to promote fruitfulness." It would thus appear that decaying trees might be revived by an insertion of branches from a vigorous wild tree, and that the custom was practised when St. Paul made use of it to illustrate the relative positions of the Jewish and Gentile churches. The practice in question was known to Pliny, and is thus spoken of by his editor, Holland (xvii., c. 18): "In Barbarie, the people have this practice peculiar to themselves; for to graft in a wild Olive stocke, whereby they continue a certain perpetuity; for even as the boughs that were graffed and (as I may say) adopted first, wax old and grow to decay, a second quickly putteth forth afresh, taken new from another tree, and in the same old stocke sheweth young and lively; and after it a third successively, and as many as need; so as by this means they take order to eternize their Olives;

insomuch as one Olive-plot hath been knowne to have prospered in good estate a world of yeares. This wild Olive aforesaid may be graffed either with scions set in a clift, or els, by way of inoculation, with the scutcheon aforesaid." Pliny himself describes the whole much more briefly, e. g.: "Africæ peculiare quidem in Oleastro est inserere. Quadam æternitate consenescunt, proxima adoptioni virga emissa, atque ita alia arbore ex eadem juvenescente: iterumque et quoties opus, sit, ut ævis eadem oliveta constent. Inseritur autem Oleaster calamo, et inoculatione."

Before concluding this part of the subject it is desirable to advert to the *trifacial orange*, a most singular production known in some places by the name of *Oranger hermaphrodite.* Mr. St. John, in his *Travels in the Valley of the Nile*, gives the following account of this very curious tree in Boghos Bey's garden at Alexandria. "Here I was shown an extraordinary fruit-tree, produced by an extremely ingenious process. They take three seeds, the Citron, the Orange, and the Lemon, and carefully removing the external coating from both sides of one of them, and from one side of the two others, place the former between the latter, and binding the three together with fine grass, plant them in the earth. From this mixed seed springs a tree, the fruit of which exhibits three distinct species included in one rind, the division being perfectly visible externally, and the flavour of each compartment as different as if it had grown on a separate tree. This curious method of producing a tripartite fruit has been introduced by Boghos Joussouff from Smyrna, his native city, where it is said to have been practised from time immemorial." This statement is illustrated by the following note to the *Gardeners' Chronicle* of 1841, from the Rev. G. C. Renouard, at that time Foreign Secretary to the Royal Geographical Society.

"When resident at Smyrna as chaplain to the factory there, in 1812, a fruit produced, as I was told, by an Orange-tree on which a Lemon had been grafted, was sent to me from the garden of a friend at Hajilar, a village in the neighbourhood, so singular in its appearance that I should have preserved it in spirits had I been aware of the circumstance I shall presently mention. Boghos Yusuf (i. e. Paul Joseph) is a most estimable Armenian, universally esteemed, and was employed in his

youth under the British Consul at Smyrna. He might, therefore, have had his tree from the same garden as that in which the one I speak of grew. The fruit sent to me had the size and appearance of a large Orange with two or three large patches of Lemon neatly stuck on it; the colour, almost to the very edges of the different pieces, being distinctly that of the respective fruits; and on removing the rind, which, as in a common Orange, was all of one piece, the portions beneath the Lemon-coloured parts had not only a considerable degree of acidity, while the Orange had its proper degree of sweetness, but they were separated from their sweet neighbours by a distinct membrane, which in some degree accounted for their difference in taste. The pulp was also, I believe, of a lighter hue. The patches of Lemon were merely superficial, and of no great thickness. They made bumps, or irregular elevations, on the rind of the fruit."

Up to the present time we have no evidence to show whether or not it is practicable to graft three embryos in the manner stated by Mr. St. John's informant? Is it physically impossible that the result should be such as is described; namely, that each fruit should consist of three parts, the one of the nature of a Lemon, the other of a Citron, and the third of an Orange? I think not. If the stems of two or three plants, when brought in contact, will adhere and become one, so may the sides of two or three embryos: and, in fact, this occurs occasionally in the Mistletoe, the Cress, the Sun-spurge, and others, without the assistance of art. Now if three embryos of different varieties could be made to unite, would their several natures be so blended as to form but one whole, consisting of a mixture of each; or would they grow in union, each retaining its own peculiar qualities? This is a question that vegetable physiology does not at present enable us to answer.

CHAPTER XIII.

ON PRUNING.

"La taille est une des opérations les plus importantes et les plus délicates du jardinage. Confiée communément à des ouvriers peu instruits, observée dans les résultats d'une pratique trop souvent irréfléchie, elle a dû nécessairement trouver des détracteurs même parmi les physiologistes. Il en eût sans doute été autrement, si on l'avait étudiée dans les jardins du petit nombre de praticiens qui ont su de nos jours la bien comprendre. Sagement basée sur les lois de la végétation, elle contribue, entre leurs mains, non seulement à régulariser la production des fruits, à en obtenir de plus beaux, mais encore à prolonger l'existence et la fécondité des arbres."

Nothing can be more just than these words, addressed to the Horticultural Society of Paris, by their President, M. Héricart de Thury; and, if they do not apply with as much force to our gardeners as to those of France, they do most fully to our foresters.

The quantity of timber that a tree forms, the amount and quality of its secretions, the brilliancy of its colours, the size of its flowers, and, in short, its whole beauty, depend upon the action of its branches and leaves, and their healthiness. The object of the pruner is to diminish the number of leaves and branches; whence it may be at once understood how delicate are the operations he has to practice, and how thorough a knowledge he ought to possess of all the laws which regulate the action of the organs of vegetation. If well directed, pruning is one of the most useful, and, if ill-directed, it is

among the most mischievous, operations that can take place upon a plant.

The object of pruning is either to influence the production of flowers and fruit, or to augment the quantity of timber, These two purposes demand separate consideration.

A. *Pruning for Flowers or Fruit.*

When a portion of a healthy plant is cut off, all that sap which would have been expended in supporting the part removed is directed into the parts which remain, and more especially into those in the immediate vicinity of it. Thus, if the leading bud of a growing branch is stopped, the lateral buds, which would otherwise have been dormant, are made to sprout forth; and, if a growing branch is shortened, then the very lowest buds, which seldom push, are brought into action; hence the necessity, in pruning, of cutting a useless branch clean out; otherwise the removal of one branch is only the cause of the production of a great many others.

This effect of stopping does not always take place immediately; sometimes its first effect is to cause an accumulation of sap in a branch, which directs itself to the remaining buds, and organizes them against a future year. In ordinary cases, it is thus that spurs or short bearing-branches are obtained in great abundance. The growers of the Filbert, in Kent, procure in this way greater quantities of bearing wood than nature unassisted would produce; for, as the Filbert is always borne by the wood of a previous year, it is desirable that every bush should have as much of that wood as can be obtained, for which every thing else may be sacrificed; and such wood is readily secured by observing a continual system of shortening a young branch by two-thirds, the effect of which is to call all its lower buds into growth the succeeding year; and thus each shoot of bearing wood is compelled to produce many others. The Peach, by a somewhat similar system, has been made to bear fruit in unfavourable climates (*Hort. Trans.*, ii. 366); and every gardener knows how universally it is applied to the Pear, Apple, Plum, and similar trees, and even to the Fig-tree.

The influence produced upon one part by the abstraction of some other part, thus shown in the development of buds which would otherwise be dormant, is seen in many other ways. If all the fruit of a plant is abstracted one year when just forming, the fruit will be finer and more abundant the succeeding year, as happens when late frosts destroy our crops. If of many flowers one only is left, that one, fed by the sap intended for the others, becomes so much larger. If the late Figs, which never ripen, are abstracted, the early Figs the next year are more numerous and larger. If of two unequal branches, the stronger is shortened and stopped in its growth, the other becomes stronger; and this is one of the most useful facts connected with pruning, because it enables a skilful cultivator to equalise the rate of growth of all parts of a tree; and, as has been already stated, this is of the greatest consequence in the operation of budding. In fact, the utility of the practice, so common in the management of fruit-trees when very young, turns entirely upon this. A seedling tree has a hundred buds to support, and consequently the stem grows slowly, and the plant becomes bushy-headed: but, being cut down so as to leave only two or three buds, they spring upwards with great vigour, and, being reduced eventually to one, as happens practically, that one receives all the sap, which would otherwise be diverted into a hundred buds, and thrives accordingly, the bushy head being no longer found, but a clean straight stem instead. In the Oak and the Spanish Chestnut this is particularly conspicuous.

Nothing is more strictly to be guarded against than the disposition to *bleed*, which occurs in some plants when pruned, and to such an extent as to threaten them with death. In the Vine, in milky plants, and in most climbers or twiners, this is particularly conspicuous; and it is not unfrequently observed in fruit-trees with gummy or mucilaginous secretions, such as the Plum, the Peach, and other stone fruits. This property usually arises from the large size of the vessels through which sap is propelled at the periods of early growth, which vessels are unable, when cut through, to collapse sufficiently to close their own apertures, when they necessarily pour forth their

fluid contents as long as the roots continue to absorb them from the soil. If this is allowed to continue, the system becomes so exhausted as to be unable to recover from the shock, and the plant will either become very unhealthy, or will die. The only mode of avoiding it is to take care never to wound such trees at the time when their sap first begins to flow; after a time, the demand upon the system by the leaves becomes so great that there is no surplus, and therefore bleeding does not take place when a wound is inflicted.

The Vine often bleeds excessively when pruned in an improper season, or when accidentally wounded; and, I believe, no mode of stopping the flow of the sap is at present known to gardeners. I therefore mention the following, which I discovered many years ago, and have always practised with success:—If to four parts of scraped cheese be added one part of calcined oyster shells, or other pure calcareous earth, and this composition be pressed strongly into the pores of the wood, the sap will instantly cease to flow; so that the largest branch may, of course, be taken off at any season with safety." (*Knight*, in *Hort. Trans.*, i. 102.) Mr. Lowe proposes collodion as a remedy for bleeding, which he found to be readily prevented by smearing wounds, immediately, with the substance. To this operation, the substance seems admirably adapted, by reason of its adhesiveness, its impenetrability, and its excessive toughness. Whether it will stop the bleeding of Vines, Walnuts, and similar trees requires to be ascertained.

All these things show how necessary it is to perform the operations of pruning with care and discretion. But, in addition to the general facts already mentioned, there are others of a more special kind that require attention. The first thing to be thought of is the peculiar nature of the plant under operation, and the manner in which its special habits may render a special mode of pruning necessary. For example, the fruit of the Fig and Walnut is borne by the wood of the same season; that of the Vine and Filbert by that of the second season; and Pears, Apples, &c., by wood of some years' growth; it is clear that plants of these three kinds will each require a distinct plan of pruning for fruit.

The pruner has frequently no other object in view than that of thinning the branches so as to allow the free access of light and air to the fruit; and if this purpose is wisely followed, by

merely removing superfluous foliage, the end attained is highly useful: it is clear, however, that in order to arrive at this end, without committing injury to the tree which is operated on, it is indispensable that its exact mode of bearing fruit should be in the first instance clearly ascertained.

The period of ripening fruit is sometimes changed by skilful pruning, as in the case of the Raspberry, which may be made to bear a second crop of fruit in the autumn, after the first crop has been gathered. In order to effect this, the strongest canes, which in the ordinary course of things would bear a quantity of fruiting twigs, are cut down to within two or three eyes of the base; the laterals thus produced, being impelled into rapid growth by an exuberance of sap, are unable to form their fruit-buds so early as those twigs in which excessive growth is not thus produced, and consequently, while the latter fruit at one season, the others cannot reach a bearing state till some weeks later. Autumnal crops of summer Roses, and of Strawberries, have been sometimes procured by the destruction of the usual crop at a very early period of the season; the sap intended to nourish the flower-buds destroyed is, after their removal, expended in forming new flower-buds, which make their appearance at a later part of the year.

The season for pruning is usually midwinter, or at midsummer; the latter for the purpose of removing new superfluous branches, the former for thinning and arranging the several parts of a tree. It is, however, the practice, occasionally, to perform what is called the winter pruning early in the autumn, as in the case of the Gooseberry, and of the Vine when weak; and the effect is found to be, that the shoots of such plants, in the succeeding season, are stronger than they would have been had the pruning been performed at a much later season. This is necessarily so, as a little reflection will show. During the season of rest (winter) a plant continues to absorb food solely from the earth by its roots; and, if its branches are unpruned, the sap thus and then introduced into the system will be distributed equally all through it; let us say from *b* to *c d* and *e* in the accompanying diagram. If late pruning is had recourse to, and the branches from *a* to *c d* and *e* are

removed, of course a large proportion of the sap that has been accumulating during the winter will be thrown away, and b to c will retain no more of it than the exact proportion which that part bears to the part abstracted. When, however, early or autumnal pruning is employed, a to c d and e are removed before the sap has accumulated in them, and then all which the roots are capable of collecting during the period of repose will be deposited in the space from b to a; consequently branches from that part will necessarily push with excessive vigour. As, however, pruning is by no means intended at all times to increase the vigour of a plant, late or spring pruning, if not deferred till the sap is in rapid motion, may be more judicious.

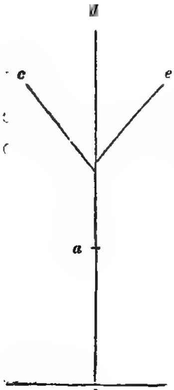

Fig. LXVII.

With regard to pruning plants when transplanted, there can be no doubt that it is more frequently injurious than beneficial. It is supposed, or seems to be, that when the branches of a transplanted tree are headed back, the remaining buds will break with more force than if the pruning had not been performed; but it is to be remembered that a transplanted tree is not in the state supposed in the case put above, Fig. LXVII. Its roots are not fully in action, and from the injuries sustained in removing, they are capable of exercising but little influence on the branches. The great point to attain, in the first instance, is the renovation of the roots, and that will happen only in proportion to the healthy action of the leaves and buds: if, therefore, the branches of a plant are removed by the pruning-knife, a great obstacle is opposed to this renovation; but, if they remain, new roots will be formed in proportion to the healthy action of the leaves. The danger to be feared is, that the perspiration of the leaves may be so great as to exhaust the system of its fluid contents faster than the roots can restore them, and in careless transplanting this may doubtless happen: in such cases it is certainly requisite that some part of the branches should be pruned away; but no

more should be taken off than the exigency of the case obviously requires; and, if the operation of transplanting has been well performed, there will be no necessity whatever. In the case of the transplantation of large trees, it is alleged that branches must be removed, in order to reduce the head, so that it may not be acted upon by the wind; but in general it is easy to prevent this action by artificial means.

In the nurseries it is a universal practice to prune the roots of transplanted trees; in gardens this is as seldom performed. Which is right? If a wounded or bruised root is allowed to remain upon a transplanted tree, it is apt to decay, and this disease may spread to neighbouring parts, which would otherwise be healthy; to remove the wounded parts of roots is therefore desirable. But the case is different with healthy roots. We must remember that every healthy and unmutilated root which is removed is a loss of nutriment to the plant, and that too at a time when it is least able to spare it; and there cannot be any advantage in the removal. The nursery practice is probably intended to render the operation of transplanting large numbers of plants less troublesome; and, as it is chiefly applied to seedlings and young plants with a superabundance of roots, the loss in their case is not so much felt. If performed at all, it should take place in the autumn, for at that time the roots, like the other parts of a plant, are comparatively empty of fluid; but, if deferred till the spring, then the roots are all distended with fluid, which has been collecting in them during winter, and every part taken away carries with it a portion of that nurture which the plant had been laying up as the store upon which to commence its renewed growth.

It must now be obvious that, although root-pruning may be prejudicial in transplanting trees, it may be of the greatest service to such established trees as are too prone to produce branches and leaves, instead of flowers and fruit. In these cases the excessive vigour is at once stopped by removal of some of the stronger roots, and consequently of a part of the superfluous food to which their "rankness" is owing. The operation has been successfully performed on the wall-trees at Oulton, by Mr. Errington, one of our best English gardeners,

and by many others, and has never proved an objectionable practice under judicious management. Its effect is, *pro tanto*, to cut off the supply of food, and thus to arrest the rapid growth of the branches; and the connexion between this and the production of fruit has already been explained. It is in some measure by pushing the root-pruning to excess that the Chinese obtain the curious dwarf trees which excite so much curiosity in Europe. Mr. Livingston's account of their practice is so instructive, and contains so much that an intelligent gardener may turn to account, that it is worth repeating here.

"When the dwarfing process is intended, the branch which had pushed radicles into the surrounding composition in sufficient abundance, and for a sufficient length of time, is separated from the tree, and planted in a shallow earthenware flower-pot, of an oblong square shape; it is sometimes made to rest upon a flat stone. The pot is then filled with small pieces of alluvial clay, which, in the neighbourhood of Canton, is broken into bits, of about the size of common beans, being just sufficient to supply the scanty nourishment which the particular nature of the tree and the process require. In addition to a careful regulation of the quantity and quality of the earth, the quantity of water, and the management of the plants with respect to sun and shade, recourse is had to a great variety of mechanical contrivances, to produce the desired shape. The containing flower-pot is so narrow, that the roots pushing out towards the sides are pretty effectually cramped. No radicle can descend; consequently it is only those which run towards the sides or upwards that can serve to convey nourishment properly, and it is easy to regulate those by cutting, burning, &c., so as to cramp the growth at pleasure. Every succeeding formation of leaves becomes more and more stunted, the buds and radicles become diminished in the same proportion, till at length that balance between the roots and leaves is obtained which suits the character of the dwarf required. In some trees this is accomplished in two or three years, but in others it requires at least twenty years." (*Hort. Trans.*, iv. 229.)

"The practice of root-pruning was long ago recognised by Switzer,

who in his *Practical Fruit-Gardener* has these words:—"Barrenness proceeds from too great an affluence of sap through those large roots, and therefore those roots ought to be taken off; yet because I have found by experience that there is some danger in the practising this upon old trees, I thought it might not be an unuseful tryal to begin first on young ones, even by taking them clear up once in two or three years, and cutting away all the great roots. This would effectually do what I desired, and it has answered accordingly." The late Mr. Beattie, gardener at Scone Palace, Perthshire, in 1811, cut the roots of Peach and Apricot-trees, on a south wall, four hundred feet long, to within two and three feet of the stems; the result was satisfactory,—over-luxuriance was checked, and fruitfulness produced. Beattie acted on the principle of depriving the tree of the means of obtaining such a great quantity of sap, thereby preventing it from growing so freely, and of course inclining it to become fruitful. Nicol suggests the same expedient, in his *Forcing and Fruit-Gardener*, fourth edition, p. 240. Indeed no gardener with ordinary powers of observation can have failed to observe the effect produced upon fruit-trees by transplantation, which is a rude kind of root-pruning. It needs but a small amount of physiological knowledge to be aware that if the roots of a plant are large and numerous, the head must be so too, for this plain reason, that *the amount of fluid food received by a plant is in proportion to the size and extent of its roots, and that food must be expended in the formation of branches.* There can be no interference with such a law as this. Suppose one tree absorbs twenty pounds of fluid food (or sap), and the other forty pounds, by the roots, all other circumstances being equal, it is evident that the one will have twice as much organizable matter as the other; and, as such matter cannot be returned back into the soil, but is irresistibly driven upwards by the force of vegetation, it can only be expended in the organization of leaves and branches; and consequently the leaves and branches will be twice as large or twice as numerous in the one case as in the other. Of course the reverse of this is equally true.

It is, however, to Mr. Rivers, of Sawbridgeworth, that we are indebted for pointing out the whole advantage and application of root-pruning, of which he has given a very full account in a paper published in the *Proceedings of the Horticultural Society*, page 136, and in his own *Miniature Fruit Garden*, to which the reader is referred.

We have still to consider that peculiar kind of pruning which is technically called *ringing* (Fig. LXVIII.). This consists in removing from a branch one or more rings of bark, by which the return of sap from the extremities is obstructed, and it is compelled to accumulate above the ring. Mr. Knight explains

the physiological nature of the operation so well that I cannot do better than quote his words.

"The true sap of trees is wholly generated in their leaves, from which it descends through their bark to the extremities of their roots, depositing in its course the matter which is successively added to the tree, whilst whatever portion of such sap is not thus expended sinks into the alburnum, and joins the ascending current, to which it communicates powers not possessed by the recently absorbed fluid. When the course of the descending current is intercepted, that naturally stagnates and accumulates above the decorticated space; whence it is repulsed and carried upwards, to be expended in an increased production of blossoms and of fruit: and consistently with these conclusions I have found that part of the alburnum which is situated above the decorticated space to exceed in specific gravity very considerably that which lies below it. The repulsion of the descending fluid, therefore, accounts, I conceive, satisfactorily for the increased production of blossoms, and more rapid growth of the fruit upon the decorticated branch; but there are causes which operate in promoting its more early maturity. The part of the branch which is below the decorticated space is ill supplied with nutriment, and ceases almost to grow; it in consequence operates less actively in impelling the ascending current of sap, which must also be impeded in its progress through the decorticated space. The parts which are above it

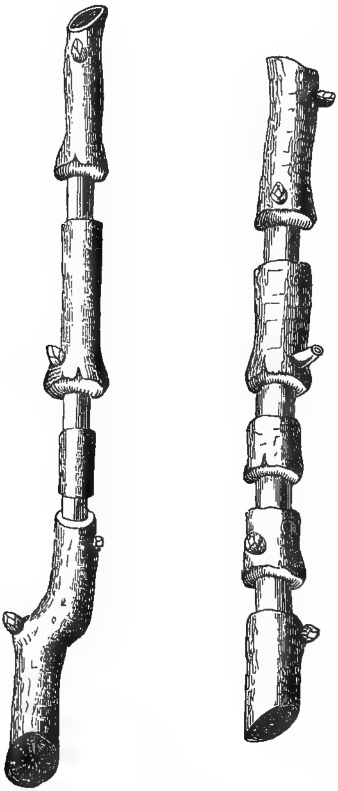

Fig. LXVIII.

must, therefore, be less abundantly supplied with moisture, and drought in such cases always operates very powerfully in accelerating maturity. When the branch is small, or the space from which the bark has been taken off is considerable, it almost always operates in excess; a morbid state of early maturity is induced and the fruit is worthless.

"If this view of the effects of partial decortication, or ringing, be a just one, it follows that much of the success of the operation must be dependent upon the selection of proper seasons, and upon the mode of performing it being well adapted to the object of the operator. If that be the production of blossoms, or the means of making the blossoms set more freely, the ring of bark should be taken off early in the summer preceding the period at which blossoms are required; but if the enlargement and more early maturity of the fruit be the objects, the operation should be delayed till the bark will readily part from the alburnum in the spring. The breadth of the decorticated space must be adapted to the size of the branch; but I have never witnessed any except injurious effects, whenever the experiment has been made upon very small or very young branches, for such become debilitated and sickly, long before the fruit can acquire a proper state of maturity."

It appears from the following case, among others, that permanent ringing is not always speedily injurious. It is recorded in the *Gardeners' Chronicle* (1842, p. 707) that a Mr. Dawson of Tottenham had a Jargonelle Pear-tree, which he planted against the gable end of a coach-house, and consequently trained higher than it could be on an ordinary garden-wall. One of the principal limbs, at a little more than a foot from its junction with the main stem, was cankered three inches of its length on one side, and for more than six inches on the other. The part affected was about an inch and a half thick one way, by three-fourths of an inch the other. Above and below the wound, the circumference was about six inches. There was not the least bark or young wood connecting the upper and lower parts of the branch, the diseased part being black and the wood extremely hard. Nevertheless this branch produced every year an abundant crop, invariably about a fortnight earlier than the rest of the tree. The fruit was not equal to that grown on the other branches, but it ripened earlier. Excepting fruit-spurs, this branch had not made an inch of wood during the last four years,

although the rest of the tree was very vigorous. There was neither bark, liber, alburnum, nor any other living substance externally on the diseased part. It was under observation for four years; and there was reason to believe that the wound was much older.

The effects of ringing, in altering the appearance of the fruit, is very striking. In the *Horticultural Transactions*, iii. 367, the following cases are reported:—In a French Crab, the fruit, by ringing, was increased to more than double the size, and the colour of it was much brightened. In a Minshull Crab the size was not increased, but the appearance of the apple was so improved as to make it truly beautiful; its colours, both red and yellow, were very bright. In the Court-pendu Apple the improvement was still more conspicuous, the colours being changed from green and dull red to brilliant yellow and scarlet. Many others of a similar kind are to be found recorded in books on horticulture. It is, however, by no means alone to the maturation or production of fruit that this operation is applicable; it will, of course, induce also the production of flowers, and it has occasionally been used for that purpose, as in the Camellia. It is best performed in the early spring, when the bark first separates freely from the wood.

This operation has, however, the disadvantage of wounding a branch severely: and, if performed extensively upon a tree, it is apt, if not to kill it, at least to render it incurably unhealthy; for if the rings are not sufficiently wide to cut off all communication between the upper and lower lips of the wound they produce little effect, and if they are, they are difficult to heal. For these reasons, the operation is little employed, other methods being used instead. By some persons ligatures are employed, and they would be preferable if they answered the purpose of obstructing the sap to the same extent as the abstraction of a ring of bark. In Malta, one of the objects of ringing, that of advancing the maturation of the fruit, is practised upon the Zinzibey, or Jujube-tree, by merely fixing in the fork of a branch a very heavy stone, made fast with bandages; its weight forces the branches a little into a horizontal direction, and thus, independently of the pressure it

exercises upon the parts it touches, obstructs the free circulation of the sap.

The details of the practice of pruning are so extremely long and minute, that the reader is necessarily referred to special works on the subject, among the best of which are George Lindley's *Guide to the Orchard and Kitchen Garden*, D'Albret's *Cours théorique et pratique de la taille des arbres fruitiers*, and Lepère *On the Peach-tree*, translated in the 8th Volume of the *Journal of the Horticultural Society*. All these works will, however, be the more intelligible if the reader keeps in view the following leading explanations, chiefly taken from notes by the author, Mr. Thompson, and others, published in the *Gardeners' Chronicle* for 1847 and 1848. The woodcuts there employed, and now reproduced, are unsurpassed, if not unequalled, for accuracy and the exact information they convey.

The Manipulation of Pruning.

By pruning is not meant hacking or mutilating trees merely to reduce their bulk, nor that sort of random cutting out which is often supposed to be expressed by the name. Those operations belong to plashing and slashing, not to pruning. Pruning is the art of removing scientifically certain branches, or parts of them. Skilful gardeners have but one way of performing this operation. Their method may be called "the clean cut;" and consists in removing a shoot by means of a sloping wound, forming an angle of about 45°, just at the back of a bud, as at *c*. The reason is, that as soon as the bud pushes, this wound is readily and rapidly covered with new wood. In some trees it will, in fact, heal over in a few weeks. An awkward way of performing this, represented at *b*, is "the cut to the quick." Here the wound is made

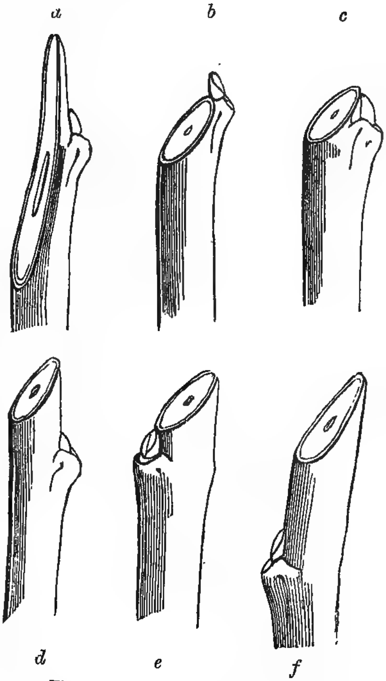

Fig. LXIX.—Good and Bad Pruning.

too low down, and exposes to the drying action of the air the communication between the base of the bud and the interior of the stem; the consequence

of which is that the bud dies, and the new shoot not only does not come where it was expected, but is surmounted by a dead joint, which will afterwards have to be removed. In order to avoid the risk of "the cut to the quick," some gardeners make use of "the snag cut" (*d, e, f,*) in which the wound is made on the same side of the branch as that occupied by the bud, slanting downwards towards it. That plan is objectionable; for it involves the necessity of leaving behind a dead portion of the branch, to be removed at a later pruning, so that work must be done twice over; moreover, it is an admission of a want of the skill required to make "the clean cut" skilfully. Lastly, there is "the slivering cut" (*a*), in which a long ragged unequal shave is taken off the branch, much too low in the beginning, and much too high at the end. It is the cut made by garden labourers. It is clumsy, ugly, awkward, and dangerous, for it is apt to injure the branch on which it is made. In all cases the amputation should be made by one firm-drawn cut. The clean cut can be performed by a dexterous operator to within a shaving of the right line: and the mastery of this art is no mean acquisition. Expert pruners will grasp a branch in their left hand, and with one sharp quick draw remove a shoot as thick as the thumb. But for this purpose a knife must be keen, and not blunt and notched, as what are miscalled pruning knives frequently are.

The Apple-tree.

The Apple-tree, left to its natural growth, forms generally a low stem, branching out into a top, which ultimately becomes hemispherical, towards the outside of which fruit-spurs, leaves, and fruit are most abundant; to support these, the branches interiorly may be considered as a sort of framework, for they are often destitute of spurs or foliage. The Apple never bears, except accidentally, on young wood. It is on wood two or more years old, and on the stunted branches, called "spurs," that its fruit appears.

This fruit being chiefly grown as a standard, it will be sufficient to mention that form.

A *Standard* should have a clean, straight, substantial stem. Every leaf which appears along it while young, should be encouraged. If any strong shoot break out let it be checked; but all other laterals should be allowed to go on at least till the end of July, when they may be stopped by pinching off their points. In the following autumn cut them off closely from the lower portion of the stem, and shorten the rest back to one eye. In the following season these eyes will push fresh shoots; treat them like their prodecessors in summer, and clear an additional portion of the stem below, in autumn, by closely cutting the laterals which may have pushed therefrom. By this mode of procedure self-supporting stems can be generally insured.

The formation of the top must now be considered. The height of clear stem being determined, the upright leader exceeding that height in summer

by several inches, must be shortened back at the ensuing winter pruning, so that the lowest of three buds immediately below the section shall correspond with the intended height of stem. These three buds will give rise to three shoots, which should be encouraged for the commencement of the branches of the tree. Each of them, as they proceed in growth, should be made to diverge at an angle of about 45°, or half way between the horizontal and perpendicular directions; and, at the same time, the shoots should be kept equidistant from each other. At the winter pruning, they should be shortened to within nine inches or a foot of their bases, particularly observing to cut above two buds pointing outwards in the direction which it would be desirable the shoots proceeding from them should take. Six limbs will be thus originated. Again a little attention in summer will ensure an equal divergence of the shoots from the perpendicular, and equal distances from each other. Meanwhile, a gradual removal of the temporary shoots on the stem is presumed to have annually taken place, as above recommended. The scars resulting from the suppression of those on the lower part of the stem will have nearly or quite healed over.

After the principal branches have been started, it is well to regulate the growth of the top for a few years longer, by checking, about midsummer, any shoots that are over-luxuriant, or that are taking a wrong direction. Afterwards, little pruning will be required. The branches should be kept thin enough to admit sufficient sun and air; and after bearing heavy crops, portions of the extremities should be a little shortened. Moreover all that cross each other so as to "whip" in windy weather, and all that are broken or cankered, should be cut out.

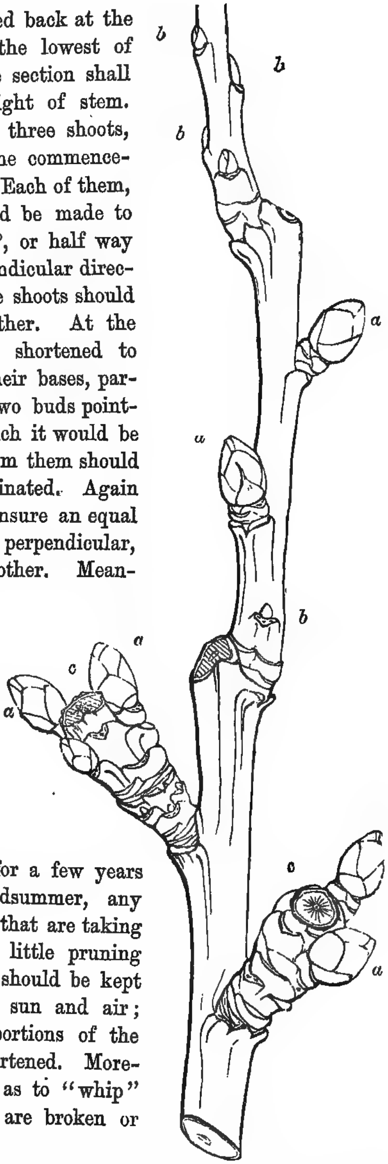

Fig. LXX.—Shoot of the Apple-tree.

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a, a, a, a, a, a, blossom-buds; *b, b, b, b, b,* wood-buds; *c, c,* scars or spurs where fruit was attached last season.

THE PEAR-TREE.

This, like the Apple-tree, bears its fruit on wood more than one year old, but chiefly on spurs, and very rarely on two-year branches. The object of the pruner is to secure spurs by stopping branches and arresting luxuriance, at the same time maintaining the plant in perfect health.

There is no difficulty in obtaining the requisite number of branches, at proper distances, by observing the following directions:—Plant a maiden tree in autumn; allow it to establish itself for one year, and then head it back to a good eye, a few buds from its base. Let one shoot grow as strong and upright as possible during the summer, and head it back to within thirteen inches of the ground in autumn, cutting very close to a bud, in order that the shoot springing from it may form little or no bending; train it upright, whilst three or four shoots, from buds immediately below it, should be more or less inclined to a horizontal direction, according to their strength; the strongest should be most depressed. These three or four constitute the commencement of the first or lower tier. For the next tier, head back the upright leader to within eighteen inches of its base, if the soil is rich; if not, to fifteen inches; and from the shoots produced in the following season from buds, just under the cut, train a shoot for a leader, and three or four somewhat horizontally, as before, for a second tier. Precisely in this manner tier after tier must be started, till the tree attain its assigned height. All this can be effected in accordance with the natural disposition of the tree to form an upright stem, and with the tendency of the sap to develope the uppermost buds of a shortened shoot. But it is not to be done without serious difficulties.

The shoots started for horizontal branches will rarely take that direction; on the contrary, they will generally diverge at an angle of 45°. This may, and should be overcome by tying down. The disparity of vigour in the upper, as compared with the lower branches, is a more serious affair. If allowed, the former will soon overgrow the latter, and the pyramid will ultimately become inverted. It is, therefore, evident that, in order to have well-conditioned pyramid Pear-trees, means must be adopted to maintain vigour in the lower tiers of branches, and repress over-luxuriance in the upper.

With the view of invigorating the lower, permit the shoots to grow without restraint till September, and then bend them towards a horizontal position. They will thus be much stronger than if they had been made to follow a horizontal direction from the beginning. Shorten them a little at the winter pruning, in order to obtain a stronger leading shoot than would otherwise be produced. Cut to a side bud; one on the upper side would produce a stronger shoot, but the latter could not be brought down without occasioning an unsightly bend. Besides a leader, some other shoots will probably be produced; let them grow, for their foliage will assist in forming channels, or layers of wood containing channels, for the transmission of sap

along these branches in the following season. The growing shoot should have its point elevated till September, as before. No reduction of foliage connected with the lower branches should be made by summer pruning. Their leading shoots must not be overshaded.

In order to prevent excessive luxuriance in the upper branches, recourse must be had to summer pruning as the most efficient means. The shoots should be trained horizontally from their origin, their points depressed instead of elevated. In short, they must be subjected to a treatment generally the reverse of that recommended for the lower branches.

Against *walls*, the horizontal mode of training answers well for the Pear. When the young tree is planted, head down the shoot to a foot, or four courses of bricks, above the level of the ground. Train a shoot upright, and one right, another left, at an angle of 45°; if these prove unequal in point of vigour, depress the strong and elevate the weak. Lower them both about the middle of September to the horizontal line represented by the joint between the fourth and fifth course of bricks. Their origin on the stem was somewhat below this line, and therefore they must ascend a little to reach it. This, as regards the lower branches, is an advantage, for the sap flows more freely into limbs thus diverging, than it does when constrained to proceed from the stem directly at right angles. The lower branches being apt to become the weakest, may be afforded this advantage, whilst towards the top of the wall the branches may be made to proceed horizontally immediately from the stem.

The tree having now a central upright shoot, and two horizontal side shoots, shorten the latter at the winter pruning according to their strength; if weak, nearly to their bases; the upright one to the fourth course of bricks above that to which the first shoot was cut. Train the shoot from the uppermost bud in a perpendicular direction, and one on each side as before. Proceed thus to obtain an upright and two horizontal branches every year till the tree reach the top of the wall. When the horizontal branches are sufficiently strong, they may be trained along the courses of bricks without shortening.

If properly managed in summer, fruit-spurs will begin to form along these branches. The accompanying cut (Fig. LXXI.) represents a spur in which *a* is progressing to form a blossom-bud, whilst *b*, *b*, are already blossom-buds, known by their plumpness; and from this period of the season such buds exhibit signs of active vegetation, but in *a* the surrounding scales remain undisturbed till late in spring. The scar at *c* is where a portion of spur that has borne fruit has been cut back, and at the winter pruning after *b*, *b*, have produced fruit, they must likewise be cut back to others likely to form at their bases, as they did at the base of *c*.

The pruning of the Pear-tree trained against an *espalier* differs in nothing from that which it requires when trained against a wall, except that the spurs of espalier trees need not be so much shortened.

In the Garden of Plants at Paris there exist certain pyramidal Pear-trees,

which may be regarded as models of that form of the tree for which the French are celebrated. Mr. Thompson describes them as being from 10 to 15 feet high, or more, having a regularly tapering outline from the base to the top, where they terminate in a single shoot. The young plant is stopped according to its strength, and so as to furnish side branches. These are not in stages at uniform distances along the stem; on the contrary, almost every shoot which breaks out from the stem is allowed to grow; but the *laterals produced on these are pinched in summer*, and even such of the leading shoots as appear likely to become too strong for the others are stopped. M. Cappe, who manages them, pinches all the young shoots, not required to form branches, *when in a very young state;* when they have scarcely pushed a finger's length, they are shortened to about one inch, or from that to one and a half inch. The portion left forms the basis of one or more fruit-buds, bearing fruit in the following season, or a spur on which blossom-buds are formed for bearing in the second season. The plan succeeds admirably in the climate of Paris. The fruit is abundant, large, and fine. The trees are healthy and vigorous, and well furnished with blossom-buds.

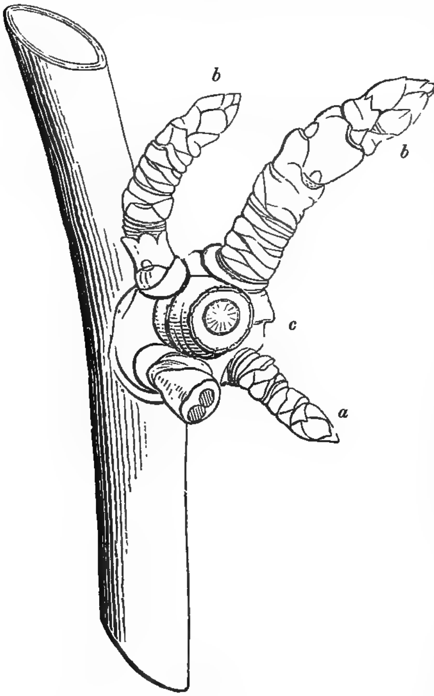

Fig. LXXI.—Spur of the Pear-tree.

Supposing the branches of a tree are properly thinned and regulated at the winter pruning, and that so far as they extend, their number is quite sufficient for the space they occupy; presuming, also, that the tree is in good health, a number of laterals are sure to spring. They are, of course, superfluous; and every one of them should be pinched as already mentioned. If the last year's shoot has been shortened at the winter pruning, then, besides the terminal one on the part left, one, two, or three next to it are almost sure to push; and these M. Cappe commences to check by pinching when about three inches in length; but those nearer the base of the shoot he allows to grow till they attain the length of six or eight inches before he shortens them. The terminal bud is of course allowed to go on for the

prolongation of the branch. It frequently happens in France, and the liability will be still more in the climate of England, that after a shoot is pinched back, the newly-formed buds on the part left will push a secondary shoot in the same season. When this is the case with those under the care of M. Cappe, *he also pinches these secondary shoots* to an inch or an inch and a half from where they originate. They rarely push again; but if they do, their growths are again reduced as before.

The Quince-tree.

The accompanying cut shows that in the preceding year a blossom-bud, similar to those marked *a*, *a*, and sessile like them, was situated at 1. In the course of last season that bud pushed a sort of shoot, furnished with leaves, and bearing at its extremity a single blossom, producing one fruit, which at its maturity had either been pulled or had dropped off, leaving a scar at *c*. The portion between 1 and *c* may be termed a branch, as it was furnished with leaves, and buds appear that were formed in the axils of those leaves; but still it is an imperfect branch, inasmuch as it has no terminal bud for its prolongation, the place of such bud having been occupied by the fruit. As this portion is only furnished with weak buds, it is not necessary to be retained, and should be cut off at 1.

If the tree is planted in rich, rather moist soil, it will send up a long but flexible shoot; and if from this all laterals are pruned closely off, with the view of making a clean stem, the latter will be rendered much weaker than it would be if left to Nature. The plant, therefore, must be cut back to within eighteen inches of the ground, more or less according to its strength. Generally three buds next the section will push in the following season; select the shoot best adapted for continuing the stem, and train it as upright as possible. Shorten this at the winter pruning, and spur in the laterals. In

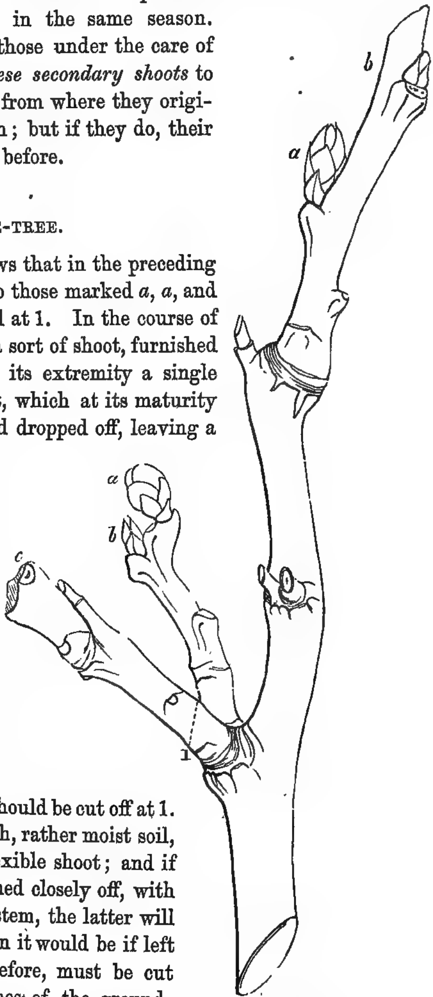

Fig. LXXII.—Shoot of the Quince-tree.

a, *a*, blossom-buds; *b*, *b*, wood-buds; *c*, the place where fruit was attached last season.

every successive year, a well-managed young tree of any kind ought to have an increased quantity of foliage; certainly not by any avoidable means should it be reduced to a condition under which it could only produce a decreased quantity. A portion should be removed at every winter pruning, but the quantity should be more than compensated by that of the young shoots produced above in the preceding summer. By attending to this, and annually shortening the leading shoot, a stout stem, requiring no stake for support, will be the result. When the stem has attained the desired height, the formation of the head should be commenced. Three shoots, cut back at least to half their length, will afford two shoots each in the following season; and thus six principal branches will be originated. Afterwards very little pruning will be required. It will chiefly consist in early checking over-luxuriant upstarts, and thinning out cross-branches.

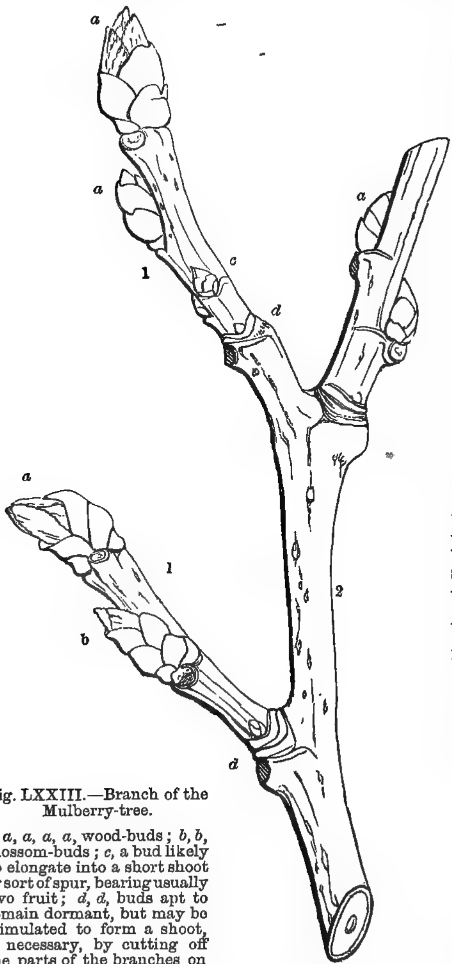

Fig. LXXIII.—Branch of the Mulberry-tree.

a, a, a, a, wood-buds; *b, b*, blossom-buds; *c*, a bud likely to elongate into a short shoot or sort of spur, bearing usually two fruit; *d, d*, buds apt to remain dormant, but may be stimulated to form a shoot, if necessary, by cutting off the parts of the branches on which they are situated immediately above them.

The Mulberry-tree.

The tree will thrive in any rich deep soil, not too stiff. It should be planted in a situation open to the sun, yet sheltered from strong winds. As a standard, it requires but little pruning, merely the removal of cross or ill-placed branches; and this should be done in autumn.

The Fig-tree.

The accompanying figure represents a shoot of the last summer's growth; on which *a*, *a*, *a*, *a*, *a*, are fruit-buds; *b*, *b*, wood-buds; *c*, *c*, *c*, *c*, *c*, *c*, scars where the leaf-stalks had detached themselves at the fall of the leaf. It thus appears that the fruit-buds of the Fig-tree are formed on the young shoots, in the axils of the leaves. Sometimes it happens that leaves are not accompanied with fruit-buds; but they are frequently formed in the axil of every leaf, from the base of the shoot to its apex. In a congenial climate, fruit-buds thus progressively formed, result in a succession of ripe fruit. But in our climate, although young Figs are produced in great abundance, they rarely acquire maturity in the same season in which they originate, unless assisted by artificial heat. Shoots may be seen plentifully furnished with green Figs, some of the latter attaining a considerable size before autumn, but seldom ripening even at that period; and then the temperature begins to decline below that which is necessary for carrying on the active vegetation of the plant; the leaves drop; the fruits still hold on; but they wither even if protected from frost. Such being the case, those fruit-buds which may be expected to yield mature fruit in the open air, are not to be looked for on the lower part of the shoots where the fruit-buds have become developed. It is towards the extremity of the shoots, where fruit-buds are yet in embryo, compact and sessile, like those represented by *a*, *a*, *a*, *a*, *a*, that we have to look for a crop. Such buds retain their vitality till the following spring, if they are not killed by frost, or cut off by a badly-directed pruning-knife. The mode of bearing will thus be readily understood, and the necessity of protecting the extremities of the shoots of Figs from frost.

"Whenever," says Mr. Knight, "a branch of this tree appears to be extending with too much luxuriance, its point, at the tenth or twelfth leaf, is pressed between the finger and thumb, without letting the nails come in contact with the bark, till the soft succulent substance is felt to yield to the pressure. Such branch, in consequence, ceases subsequently to elongate; and the sap is repulsed, to be expended where it is more wanted. A fruit ripens at the base of each leaf,

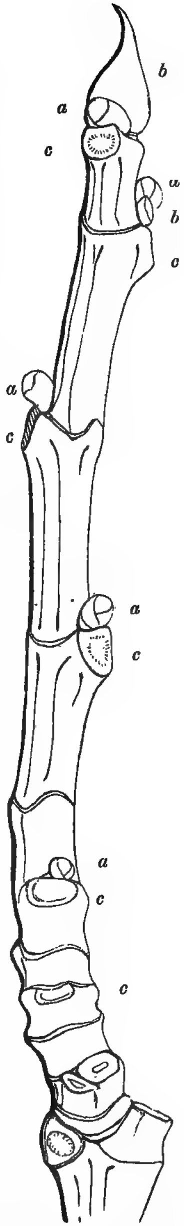

Fig. LXXIV.—Shoot of a Fig-tree.

and during the period in which the fruit is ripening, one or more of the lateral buds shoots, and is subsequently subjected to the same treatment, with the same result. When I have suffered such shoots to extend freely to their natural length, I have found that a small part of them only became productive, either in the same or the ensuing season, though I have seen that their buds obviously contained blossoms. I made several experiments to obtain fruit in the following spring from other parts of such branches, which were not successful: but I ultimately found that bending these branches, as far as could be done without danger of breaking them, rendered them extremely fruitful; and, in the present spring, thirteen Figs ripened perfectly upon a branch of this kind within the space of ten inches. In training, the ends of all the shoots have been made, as far as practicable, to point downwards." — *Hort. Trans.*, iv. 201.

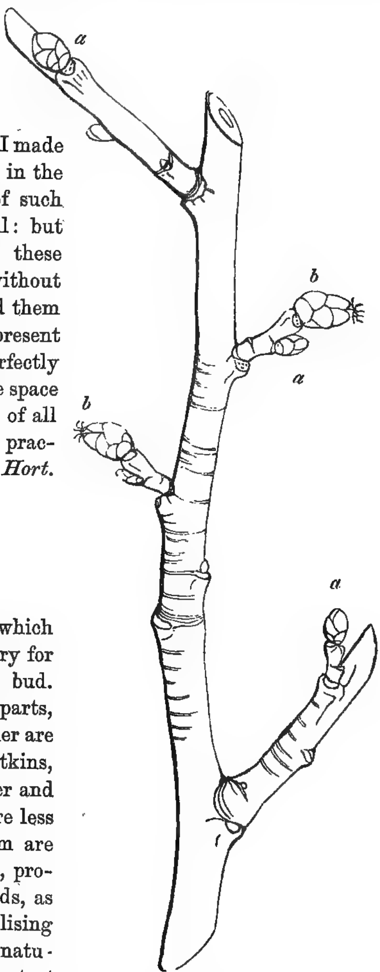

Fig. LXXV.—Branch of the Filbert. *a, a, a*, wood-buds; *b, b*, blossom-buds.

The Filbert-tree.

The Filbert-tree is one of those which does not contain all the parts necessary for the production of fruit in the same bud. Some buds develope only the male parts, and others only the female; the former are comprised in those pendant yellow catkins, easily recognised in the end of winter and early spring. The female portions are less conspicuous, all that appears of them are some slender, deep crimson stigmas, protruding beyond the apex of the buds, as represented at *b, b*. On these, fertilising particles from the catkins either fall naturally, or are otherwise brought in contact with them whilst being blown about by the winds; and fruitfulness is the result. If, on the contrary, there are no catkins, or if they are prematurely cut away in pruning, there can be no fruit. Pruning should not be commenced till after the appearance of the crimson stigmas at the apex of such buds as *b b*,

and after the full expansion of the catkins. When the latter have fulfilled their purpose, they fall off. After fertilisation, the buds *b*, *b*, lengthen into a twig much the same as other buds; but towards midsummer the formation of the cluster can be seen. The cluster is always terminal.

The county of Kent has been long celebrated for the production of large crops of Filberts. The method pursued by the Maidstone cultivators is minutely detailed by the Rev. William Williamson in the fourth volume of the first series of the *Transactions of the Horticultural Society*.

"Plant the bushes unpruned, and after being suffered to grow without restraint for three or four years, cut them down within a few inches of the ground. From the remaining part, if the trees are well rooted in the soil, five or six strong shoots will be produced. In the second year after cutting down, these shoots are shortened; generally one-third is taken off. If very weak, I would advise that the trees be quite cut down a second time, as in the previous spring; but it would be much better not to cut them down till the trees give evident tokens of their being able to produce shoots of sufficient strength. When they are thus shortened, that they may appear regular, let a small hoop be placed within the branches, to which the shoots are to be fastened at equal distances. By this practice two considerable advantages will be gained—the trees will grow more regular, and the middle will be kept hollow, so as to admit the influence of the sun and air. In the third year a shoot will spring from each bud; these must be suffered to grow till the following autumn, or fourth year, when they are to be cut off nearly close to the original stem, and the leading shoot of the last year shortened two-thirds. In the fifth year several small shoots will arise from the bases of the side branches which were cut off the preceding year; these are produced from small buds, and would not have been emitted had not the branch on which they are situated been shortened, the whole nourishment being carried to the upper part of the branch. It is from these shoots that fruit is to be expected. These productive shoots will in a few years become very numerous, and many of them must be taken off, particularly the strongest, in order to encourage the production of the smaller ones; for those of the former year become so exhausted that they generally decay; but whether decayed or not they are always cut out by the pruner, and a fresh supply must therefore be provided to produce the fruit in the succeeding year. The leading shoot is every year to be shortened two-thirds, or more should the tree be weak, and the whole height of the branches must not exceed six feet. The method of pruning above detailed might, in a few words, be called a method of spurring, by which bearing shoots are produced, which otherwise would have had no existence. Old trees are easily induced to bear in this manner, by selecting a sufficient number of the main branches, and then cutting the side-shoots off nearly close, excepting any should be so situated as not to interfere with the others, and there should be no main branch directed to that particular part. It will, however, be two or three years before the full effect will be produced."

The management of the laterals must be varied according to the nature of the soil, and the greater or less humidity of the climate. If the soil is rich and moist, strong shoots, too strong for any but wood-buds being formed on them, will be produced. Instead of the fruitful laterals produced on the Kentish soil, rod-like walking canes will be produced when the plants are grown in many other parts of the kingdom. They must be cut back, otherwise they would form strong cross branches; but then we must consider that each of these rods, with their ample foliage, has contributed to the formation of roots during the summer; that these roots will be adequate to supply nourishment in the following season to all the shoots made in the present season; but when the shoots are necessarily reduced, say more than one half, either by shortening or cutting out entirely, then the remaining portion has more than double the quantity of roots necessary for its nourishment; and it will, in consequence, be stimulated to grow with excessive luxuriance.

The Peach and Nectarine-tree.

The mode of bearing is as follows:—A, represents the branch of a Peach-tree. The figures 1, 2, 3, 4, 5, denote the respective ages of the portions of branch opposite. The asterisks at the sides of the shoots, indicate the place to which these may be shortened at the winter pruning. B, is a portion of a bearing shoot furnished with both wood and blossom-buds; *a, a, a, a*, are blossom-buds; *b, b, b, b*, wood-buds.

Peach and Nectarine-trees bear their fruit exclusively on wood of the preceding summer's growth. For example, if one pull a Peach in the summer of 1847, it must be from wood formed in the summer of 1846, and which had no existence, as a shoot, in 1845, although then its origin might have been traced to a vital point within a bud. Such an almost invisible point was the shoot B, in 1845. In summer 1846, this point, developed from a bud, grew a shoot, furnished with leaves disposed singly, in twos or in threes, along the growing shoot. In the axil of each of these leaves, the rudiments of a bud were formed. The leaves, having accomplished their office, dropped in autumn, whilst the energy of the young buds continued to increase. Their winter appearance is represented in Fig. B. The blossom-buds are distinguished by their plumpness: they have an ovate form, which gradually becomes globose: they have a hoary appearance, owing to the scales opening and exposing their downy integuments. The wood-buds are slender and conical. Their scaly covering is less deranged by expansion of their interior parts in early spring, and consequently they exhibit less of that hoary pubescence by which the others are distinguished. In the case of triple buds the middle one is generally a wood-bud.

The Peach differs materially from the Pear and Apple-trees. In these a shoot may be shortened to any bud, and the one immediately below the cut will almost invariably produce a shoot; but the Peach shoot must be cut to where there is a wood-bud; for if cut to a blossom-bud only, no shoot can

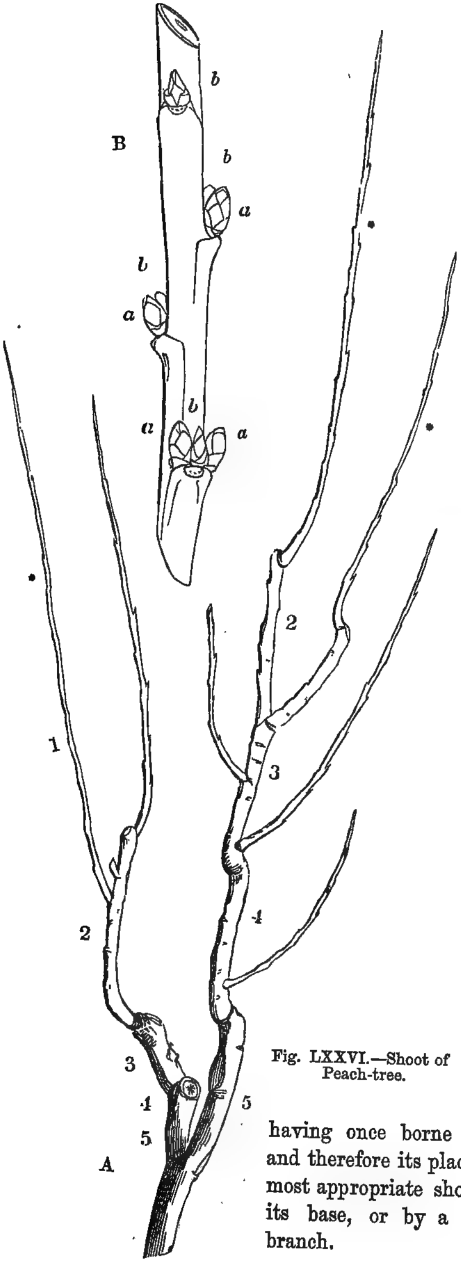

Fig. LXXVI.—Shoot of Peach-tree.

result. Sometimes all the buds on a shoot are blossom-buds, except the terminal one and one or two at the base. Such shoot must either be left its entire length, or cut back to the wood-bud at its base. The shoots of the Peach naturally terminate with a wood-bud. If this be cut off, the blossoms on the part left will expand and the fruit may set, but all will prematurely drop; thus, if all the buds marked *b* were blossom-buds, they would expand; but the eight blossoms would either drop without setting, or the fruit would drop at the time of stoning; at all events, a leafless, budless shoot would result, incapable of further vegetation. It dies downwards to the first wood-bud. The blossom-buds, *a* of B, will produce four Peaches, but one is enough to leave to come to perfection. From the wood-bud, *b*, shoots will proceed; these, in the course of the summer, will form buds for future bearing; and a twelvemonth hence they will appear similar to those on B, which having once borne fruit can do so no more, and therefore its place must be supplied by the most appropriate shoot it produces at or near its base, or by a shoot from an adjoining branch.

These facts are the foundation of all the long intricate plans for pruning and training this tree. The following are, I think, the best *concise* directions which have yet been given on this subject:—

"Commencing with the winter pruning, the first rule to be laid down as a basis for all the rest, is to shorten every shoot in proportion to its strength, and to prune to where the wood is firm and well ripened: this will cause all the pithy and unripened wood to be removed, thence ensuring a supply of that which is better ripened for the ensuing year. But in order to give every facility to the ripening of this wood, it must be trained thin, not in profusion according to the general custom, but such shoots only as may be required for the following year.

"Trees which have arrived at a bearing state should have their strongest bearing shoots shortened to twelve or fourteen inches, those next in strength to eight or ten, and the weaker ones to four or six inches, pruning each to what is termed a treble eye, or that where there is a blossom-bud on each side of wood-bud: where branches are not in a bearing state, these treble eyes will not be found; they must therefore be pruned to a wood-bud alone, which is always known by its sharp point.

"In May, the season for disbudding the tree, all foreright shoots, as well as those from the back, must be carefully removed with a sharp small bladed knife, taking care to cut close to the branch, but not into the bark: a few, however, of these foreright shoots had better be cut within a quarter of an inch only, which will leave two or three leaves to each, to shade the young fruit, and such slight wounds in the branch as have been occasioned by cutting the shoots off close.

"As soon as the young shoots have grown long enough, the leading one from each branch should be nailed neatly to the wall, selecting one or two of the side shoots produced lower down the branch, and training them parallel also. This applies to those of the stronger branches, at and near the extremity of the tree. Those in the middle and near the bottom, will allow of but one shoot probably in addition to the leaders; this will depend upon the space left in the winter pruning; if sufficient, it is always better to have a young shoot on each side as well as the leader, than to have only one, for it is by this arrangement that a succession of young wood can be kept up throughout every part of the tree.

"Should young shoots, indicating extraordinary vigour, any where make their appearance, they should immediately be cut out, unless where a vacant part of the wall can be filled up, because an excess of vigour in one part of the tree cannot be supported without detriment to the other. Peach-trees, when in a state of health and vigour, generally throw out laterals from their stronger shoots; when this is the case, they should not be cut off close, but shortened to the last eye nearest the branch; and if there is room, one or two of those first produced may be nailed to the wall; or the middle shoot may be cut out, leaving the two lowest laterals, and allowing them to take its place; thus frequently obtaining two fruit-bearing

branches, when the former one would in all probability have been wholly unproductive of fruit the following year."

THE APRICOT-TREE.

The accompanying cut represents a portion of an Apricot branch, consisting of one and two-year old wood; the former marked 1, the latter 2. *a, a, a, a, a, a, a, a, a, a*, are blossom-buds; *b, b, b, b, b, b*, are wood-buds.

It will be observed that blossom-buds are produced on the young wood and on short spurs on the two-year old wood; they are also produced on such spurs on wood three, four, or more years old. The principal branches must therefore be trained wider apart than those of Peach and Nectarine-trees, but in other respects they should be regulated by the same principles, which need not be repeated. The main branches of the Apricot may be fifteen inches apart.

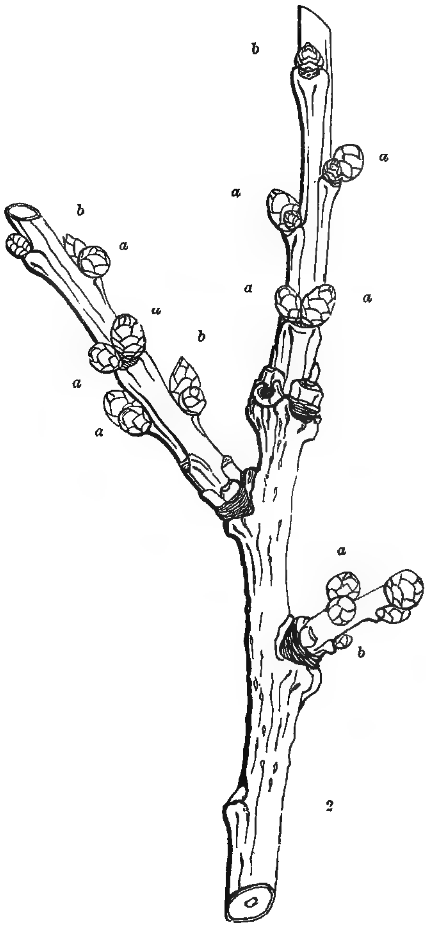

Fig. LXXVII.—Branch of Apricot-tree.

The spaces between the main branches should be occupied by younger wood, which may be allowed to bear for several years, and before it is removed, a young shoot should be encouraged for succession. Shorten the shoots more or less according to their strength, the weakest requiring to be most shortened, but seldom to less than six inches, whilst the stronger may be left as long as eighteen inches. A shoot not wanted to be laid in may be shortened at the winter pruning, to form a spur; and when the spurs extend too far they should be cut back to buds near their bases.

The Plum-tree.

xamining the buds of the Plum-tree, it will be found that the wood-re so sharp-pointed that there is little danger of mistaking them for blossom-buds, the latter being obtuse. In the wood-buds the rudiments of the leaves are convolute, rolled nearly round each other, and so as to form a sharp cone, having the growing point in the centre at the base. As they increase in size the blossom-buds show more disposition to expand outwards than to become elongated. Although the Plum and Cherry are in many respects closely allied, yet they differ essentially as regards their leaf-buds. In those of the Plum the rudiments of the leaves are rolled up as above explained; in those of the Cherry they are simply folded.

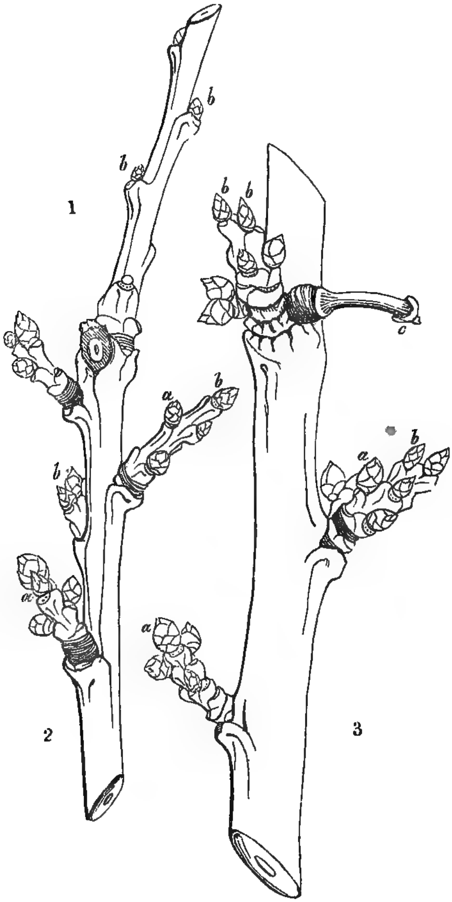

Fig. LXXVIII.—Shoots of the Plum-tree.

1, portion of shoot one year old.
2, two-years old wood.
3, three-years old do.
a, a, a, a, blossom-buds.
b, b, b, b, b, b, b, wood-buds.

When the stem of a standard Plum-tree has attained sufficient height let it be headed back to three buds above the place from whence the lowest limb is required to proceed. Encourage three shoots from these upper buds to grow at full length during the summer; and at the winter pruning shorten each of them to about a foot in length. Two shoots from each of these three so cut back will originate six principal limbs to form the head. Most cultivated varieties of the Plum have naturally spreading tops, so that the principal care requisite in pruning, after the head has been

formed, is to prevent in time any shoots from crossing others, and thinning such as appear likely to cause too much obstruction to light.

In forming a trained tree, let the maiden plant be headed back, when planted in autumn, to within a foot of the ground. In the ensuing summer train a shoot on each side, and the one from the uppermost bud upright. Now this upright one will naturally grow much stronger than the others, and the consequence will be that when all three are headed back at next winter pruning the buds on the base of the strongest shoot, that is the central one, will produce much stronger shoots than those on the lower side shoots, which are destined to furnish ultimately the lower part of the wall. It is therefore desirable that the vigour of the central shoot should not, in any degree, exceed that of the side ones; and in order that it may not do so, recourse must be had to the means of checking its luxuriance in summer. These are, pinching off its top before midsummer, inclining it from the perpendicular; and if these are not fully effectual, the leaves on its upper part may be clipped across to the extent of half their length.

At the winter pruning, shorten the three shoots to within nine inches of their bases. Train two from each of the side ones, and three from the central one. Proceed thus till a sufficient number of branches are originated, always taking care to check in time any that are likely to become over-luxuriant as compared with others. If the wood is well matured, the terminal shoots need not be shortened where additional branches are not required. When the trees come first into bearing, the spurs require only a little thinning; but as they elongate and extend too far from the wall, they must be shortened back to buds near their bases.

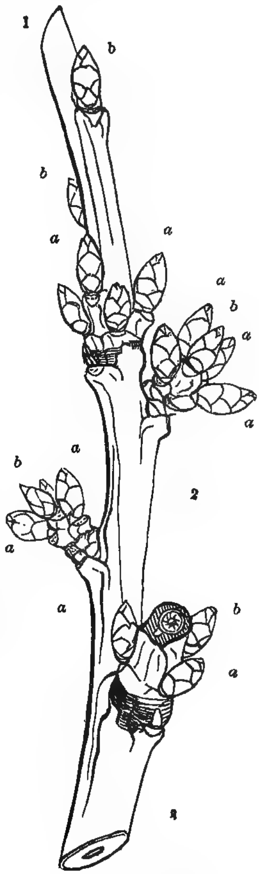

Fig. LXXIX.—Shoot of a Cherry-tree.

1, part of a shoot one year old.
2, wood two years old.
3, wood three years old.
a, a, a, a, a, a, a, a, a, blossom-buds.
b, b, b, b, b, wood-buds.

The Cherry-tree.

The Cherry-tree bears its fruit chiefly on spurs formed on wood of two, three, or more years old; and frequently fruit-buds cluster round the base of the last year's shoot. In the Morello the fruit is chiefly borne on the young wood.

Grown as a standard, the terminal shoots

seldom require to be at all shortened after a sufficient number has been obtained. Care should be taken that the branches are not too numerous in the first instance; for Cherry-trees are apt to gum when large branches are cut out; and therefore the necessity for so doing should be prevented whilst the tree is young. Espalier trees should have the branches trained horizontally, but with an inclination upwards from the stem in the first instance. The branches may be a foot apart in the May Duke varieties, but rather wider in the case of those with large leaves, like the Bigarreau, Elton, &c. The terminal shoots need not be shortened.

Wall-trees are best trained fan-shape. After a sufficient number of branches has been obtained, the shoots may be laid in at full length. All fore-right shoots should be pinched back to one or two inches in the beginning of June. The Morello, however, requires that a sufficient number of young shoots be annually preserved for bearing, and in order to afford them room, a portion of those that have borne must be cut out.

In the *Guide to the Orchard and Kitchen Garden*, the brief but excellent practical directions are these:—

"Standard Cherries for the orchard require the same management, generally, as standard Apples, and the same method may be pursued as directed under that head; but as the former of these are more generally raised from buds than from grafts, they will at first require a different treatment, namely, that of heading them down the first year. On this account they ought never to be planted later than the end of October, or the middle of November: this early planting will enable the trees to make fresh roots previously to the spring, when, in April, as soon as the buds begin to break out, they should be headed down to within three or four inches of the place where they had been budded. If the trees be good, there will be a sufficient number of eyes to produce as many shoots as will be required to furnish the head: should more than four be produced, they should be reduced to this number, of such as are the best placed. These must be allowed to extend at length without being shortened, nothing further being required than to cut out superfluous shoots, so as to keep the head uniform and handsome. If the heads of young trees be carefully attended to the first three or four years, they will rarely get into confusion afterwards.

"Espalier Cherries, and those trained against the wall, require precisely the same management, both as to pruning and training. For this purpose, trees which have been grafted are always to be preferred to those which have been raised from buds: they must be cut back at the commencement, as directed for Apricots; but the branches, except in Morellos, must be trained horizontally instead of obliquely, and always continued at their full length. In Dukes and Hearts the branches should be eight or nine inches apart, beginning at the bottom of the tree, and continuing each additional shoot in a parallel direction, till the number of series the wall will permit be completed."

THE GOOSEBERRY-BUSH.

Left to its natural growth, the Gooseberry becomes an almost impenetrable thicket, not at all adapted for producing such fine fruit as is produced by plants properly cultivated and pruned.

In the accompanying cut it will be seen that the wood-buds, *a*, *a*, *a*, *a*, are on the last summer's shoot, whilst the fruit-buds, *b*, *b*, *b*, *b*, are on two-years old wood, and produce the largest and finest fruit, but they may be seen on wood much older. The buds marked *a*, are called wood-buds, because from them young shoots are produced, but usually not from all of them; for it appears, that of the buds on the two-years old wood, which, a twelvemonth back, were similar to those now marked *a*, three had produced shoots, *c*, *c*, *c*, and the others formed the fruit-buds, *b*, *b*, *b*, *b*.

After the plants have formed shoots, these must be shortened according to their strength; if moderately strong, to about six inches. In shortening, care must be taken to cut to a bud pointing the most towards the direction which the branch should follow, in order to complete the form in which the plants are intended to be kept. The general mode is to keep the bush hollow in the middle, and six, eight, or ten branches, at equal distances, or as nearly so as possible. If two branches are likely to approach too near each other, one or both must be cut to buds pointing in the opposite direction; thus, in the accompanying figure, supposing the branch were intended to be prolonged more towards the left, then the young shoot is properly cut, as represented, for the uppermost bud *a* to proceed in that direction. On the contrary, if the uppermost bud *a* had been on the inside of a shoot, of which it would have been desirable that the direction should be outwards, towards the right, then it would have been entirely wrong to cut at that bud.

Observing thus to cut at proper buds, each leading branch may be made to diverge out-

Fig. LXXX.—Shoot of Gooseberry-bush.

a, *a*, *a*, *a*, wood-buds.
b, *b*, *b*, *b*, fruit-buds.
c, *c*, *c*, young shoots cut back.

wards, or to either side, to an extent sufficient for ordinary cultivation. The pruning of one of the leading branches may now be detailed from its commencement. In autumn, or early part of winter, the shoot ought to be shortened to some extent, bearing in mind that generally the three buds immediately below the section will break into shoots: therefore, it will be advisable to cut where another leader is required to originate. This is the first winter pruning. The second will consist in shortening the leading shoot about one-third; and also the other shoot intended for an adjoining leader. If there should be another young shoot growing strongly where not wanted, it may be cut off close; and others, weaker, may be cut like that marked *c* on the right of the engraving. The next season the leader should be shortened, and laterals cut to one eye, if weak, but otherwise three or four eyes may be left on these, some of which will probably break into shoots, and others will form fruit-spurs. The other branches will require a similar treatment. Young shoots should be trained up to supply the place of any branch exhibiting symptoms of decay.

In the midland and northern counties an open cup form of bush is generally aimed at in pruning; on the contrary, in some cases in the south, although the branches are pruned and thinned, yet some are left in the centre for the purpose of shade, otherwise the fruit would be scorched.

The Currant-bush.

Under every mode of training, the red Currant, and also the white, require to be regularly pruned every year. In rearing the young plants, the first thing to be aimed at is a clear stem, about five inches in length, free from suckers. In preparing the cutting, care should be taken to remove all the buds on the portion intended to be inserted in the ground, otherwise many of them would form suckers, injurious to the plants, and troublesome to displace effectually. In some cases cuttings can be obtained long enough to afford at once the proper length of stem; but when such cannot be had, when the cutting is altogether too short, or proves so after the necessary removal of the imperfectly formed wood at top, then three buds above the surface of the ground will be sufficient. These will generally produce three shoots, all of which may be allowed to grow during the first summer after the cutting has been planted, in order to assist in forming roots. Supposing the plant is intended for the open ground, and that it is to be trained in the usual way, open in the centre; then in autumn, after the leaves have fallen, two out of the three shoots which the plant has made should be cut off, and the third, selected as the most eligible for a stem, should be shortened, so that the third bud below the cut may be five inches above the ground. Three shoots will generally be produced the following summer. In autumn the plants will require to be planted out where they are to remain, and at the same time the shoots should be cut back to about four inches, taking care to cut above buds pointing outwards. We have now a stem five inches high,

and three branches diverging from it, each of them shortened to about four inches. Two shoots should be encouraged from each of these three, so that in autumn the plant will have six shoots, corresponding with the ultimate number of branches necessary. All other shoots must be spurred to within an inch of their bases. The six shoots selected for leaders should be cut back so as to leave them from four to six inches long; and, like those of the former season, they should be cut to buds pointing outwards. At every future winter pruning the terminal shoots of the six branches should be shortened to between four and six inches long, according to their strength. When the branches nearly attain the intended height, the terminals may be shortened to two or three buds. With regard to the lateral shoots, they must all be cut to within an inch of the old wood at every winter pruning.

Fig. LXXXI.—Shoot of Currant.

a, a, a, a, wood-buds. *b, b,* fruit-buds. *c, c, c,* clusters termed fruit-spurs; they consist chiefly of fruit-buds, but amongst them there are generally some wood-buds which produce small shoots.

When Currants are intended to be trained against a wall, they should be planted three feet apart, and a strong shoot trained upright for a stem. This should be shortened to six inches, and the two uppermost shoots trained horizontally right and left. From these, four upright shoots should be trained, so that the distance between them may be nine inches. In order that these may not run up without being sufficiently furnished with fruit-spurs, they should be shortened to six inches, and every year, at the winter pruning, the upright terminal shoots of the branches should be shortened according to their strength, shorter if weak, and if strong they should not be left longer than is consistent with their breaking into spurs not more than six inches apart. The laterals may have their points cut off annually in June, and cut nearly close to the old wood at every winter pruning.

No fruit is more improved than the Currant, by good pruning. When left to itself both bunches and berries are small and worthless; it is only when carefully thinned, skilfully pruned, and annually divested of old spurs, that the fruit acquires its proper excellence.

The Raspberry-bush.

The accompanying figures represent wood of the preceding summer's growth.

The portion with buds marked *a*, *a*, is from the upper part of the shoot; that with buds marked *b*, is taken from the lower part of the shoot or cane. The buds *a*, *a*, can scarcely be termed blossom-buds, inasmuch as they do not contain the rudiments of flowers like the blossom-buds of the kinds of fruits previously noticed; but each of them possesses the power of producing a branchlet, and on this blossom-buds are formed. The buds *b*, *b*, on the lower part of the cane, do not generally push unless the upper have been cut away, and then the lower are stimulated, producing, however, shoots and fruit later in the season than those obtained from the buds *a*, *a*. Advantage is sometimes taken of this to procure a succession of fruit in autumn.

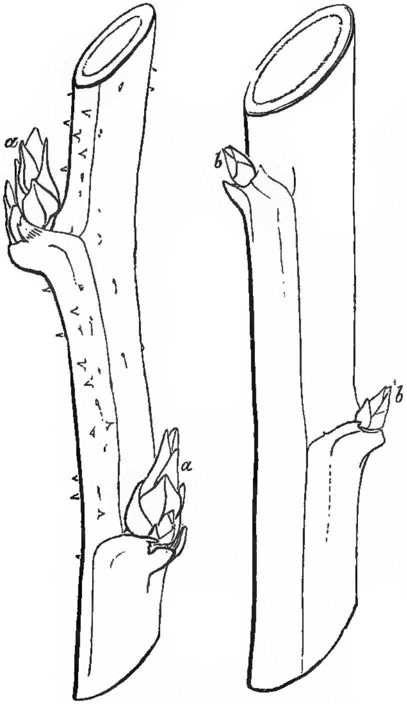

Fig. LXXXII.—Wood of the Raspberry.

Raspberry shoots or canes, it is well known, grow up in one summer, produce fruit in the next, and then die to the ground, a succession having, in the meanwhile, sprung up. The pruning usually consists in the obvious operation of cutting away all the dead wood, that which has borne fruit; and in shortening that which is alive, thinning the canes so as to leave three, four, five, or six from a plant according to its strength.

An improvement may, however, be effected on this general mode; and this improvement cannot be better explained than it is in the *Guide to the Orchard and Kitchen Garden*, p. 481:—"As the finest and best of these fruits are, in all cases, the produce of strong and well-ripened canes, it becomes necessary that the stools should have every advantage afforded them. This may be readily effected by causing all the former years' canes to be cut down to the ground as soon as they have produced their crop,

instead of allowing them to stand till the winter or spring; this removes an unnecessary incumbrance, and at a season when sun and air are of infinite importance to the young canes, consequently to the succeeding crop of fruit."

In autumn, or the early part of winter, the young canes should be shortened to about four-fifths of their original height, or to the place where the growth of the upper part of the shoot forms a sort of bending or twisting. They may then be either tied to stakes or arched, by tying their tips to those of the adjoining plant. When a late succession of fruit is desired, some plants may have all their shoots cut back to within a few inches of the ground.

B. *Pruning for Timber.*

To procure flowers or fruit forming no part of the object of those who grow trees for the sake of their timber, the principles which ought to guide the forester are of quite another class from those just explained. The forester desires, 1. to obtain the greatest possible quantity of timber in the shortest possible time; and, 2. to secure trees with tall straight stems, except in those cases where crooked timber is required for ship-building. Of the latter there is generally no deficiency in consequence of the accidents to which trees are liable; or it may be readily provided by artificial methods that must suggest themselves to every one practically, if not theoretically, acquainted with the laws which regulate the growth of trees. The two first objects are all that need be considered on the present occasion.

Timber is the woody texture of a tree. The woody texture does not form itself; it does not grow independently of all other parts; it is only a portion of a living system, arising from the action of other organs; it is to a plant what flesh and bones are to an animal. The bones and flesh of cattle are not increased in quantity of themselves, but by means of food swallowed by the mouth, and digested by the stomach. To swallow food without digesting it is an entirely useless operation both in the animal and vegetable kingdoms. The digesting organs of trees are their leaves; it is the foliage which constitutes the stomach of a plant; therefore, to deprive a plant of its leaves is like depriving an animal of its stomach.

Emaciation is the consequence in both cases; it is indicated in animals by leanness and debility; in plants, by the loss of woody texture, or timber. But a plant has not a single stomach, as an animal has; it is covered with stomachs in the form of leaves, every one of which performs its part in the action of digestion, and so contributes something to the formation of wood. (See page 72.) Although out of the millions of leaves that clothe a tree many may be destroyed, and no appreciable diminution of the wood be remarked, yet it is certain that some diminution takes place; when the destruction of leaves is excessive, the diminution will be excessive also. We should be a long time emptying a fish-pond with a tea-spoon; but in time we should succeed; and the only effect of using a pump for the purpose would be to accelerate the operation.

Pruning is nothing less than the removal of leaves. To cut off a branch in summer is evidently so; and if the branch is naked still its removal is the destruction of the part from which leaves would have been produced had it been permitted to remain. The effect of violent pruning, as illustrated by Pontey's barbarous method of trimming trees into poles is now notorious; it shows the consequences attendant upon pruning trees excessively. Upon less pruning less evil results; but the difference is only one of degree.

Prune not at all—should therefore be the maxim of a forester. Plant thickly, thin constantly, stop carefully, and leave the rest to nature. But unfortunately it does not happen that he who plants well always thins constantly; it is still more rare that stopping is thought of, and so a maxim, one of the soundest in the whole system of foresting, cannot be observed. Hence pruning may be regarded as a necessary evil, to which the wise must submit because of the ignorant; the careful to cure the evils inflicted by the careless.

Stopping consists in destroying the point or last buds of a branch while young and in process of formation; the finger and thumb can perform the operation without aid. *Pruning* is the removal of a branch already formed, and must be executed with a cutting instrument. Stopping prevents the formation of

useless parts, compelling a tree to expend its force in the production of what is valuable; pruning is the abstraction of useless parts upon forming which a tree has expended some part of its power. Stopping is prevention; pruning is cure—or is intended to be.

The respective effects of doing nothing, stopping, and pruning may be illustrated by diagrams. Let A represent a young tree disposed to be bushy-headed, all its branches being equal. If nothing is done to such a plant, each branch will grow larger at an equal rate, and produce a few laterals; by the end of a second season the tree will be somewhat larger, but in other respects much what it was before, as is shown at B.

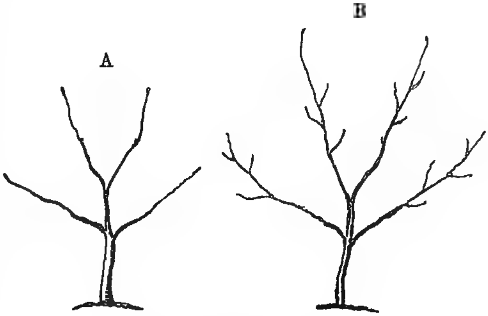

Fig. LXXXIII.

But suppose that A, instead of having been left untouched, had had three of its branches stopped by breaking off their points, as is shown at C. In such a case the current of sap being arrested in the laterals, would flow strongly into the leader, which would lengthen rapidly, while the laterals would only produce some small spray; and the result, at the end of a second year, would be what is represented at D. In this case the tree would have been very little deprived of its foliage, and yet the production of a permanent leader would have been effected as well as if the pruning-knife had been employed, or indeed

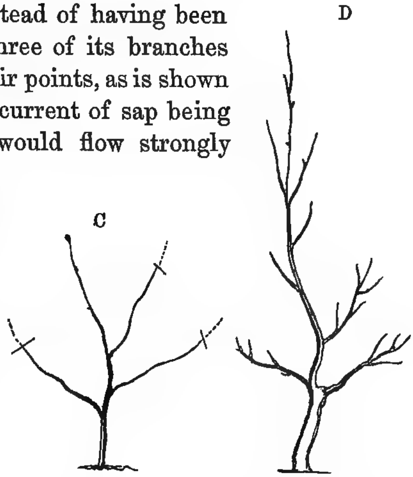

Fig. LXXXIV.

much better. For observe the contrast. E represents the same plant A pruned up to a leader by the total removal of its lateral shoots in the usual way. F will show what such a plant may be expected to become at the end of the season, instead of D, which it would have been under the influence of stopping only.

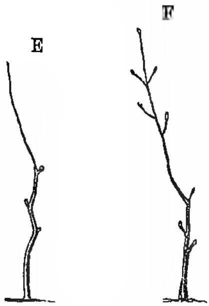

Fig. LXXXV.

The same observations will apply to cases where a pair of leaders contend with each other, as at G. If one of the leaders only is broken off and stopped, as at *a*, scarcely any of the energy of the tree will be destroyed, but the sap will be thrown into one of the leaders much more than the other; and at the end of the season the plant may be expected to resemble H. If, however, instead of being treated thus, G be deprived of all its laterals, and left by the pruner as at I, the digesting powers of the plant will be so completely removed that we can hardly expect it to become at the end of the first year better than at K—the difference between which and H is manifest.

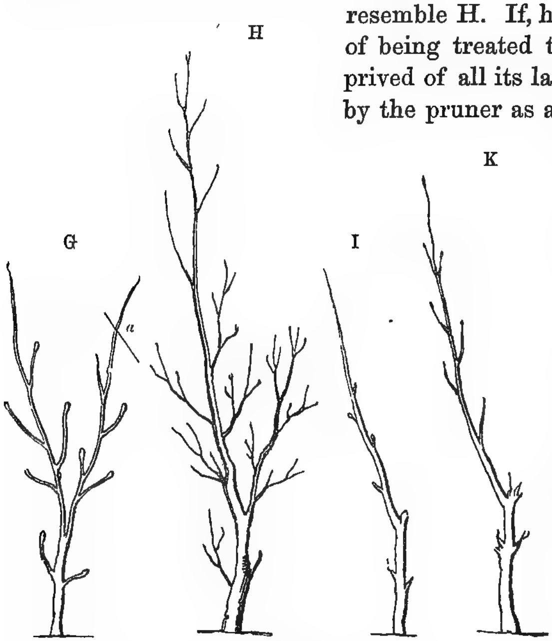

Fig. LXXXVI.

These diagrams explain the true principles of managing young forest-trees, so far as controlling their form is concerned. They are now recognised

by all intelligent foresters. Mr. Billington pointed out their importance in 1825, thus showing how low the art of arboriculture had at that time fallen, for they were well known in the days of Miller and Duhamel, and were carefully observed by the great Norfolk planters when the author was a boy.

When trees are young, most, except Conifers, have a tendency to form bushy heads, or many branches of equal strength; and, when neglected, such plants are long in forming timber, if they ever do form it; and they seldom produce a clean straight trunk. In order to meet this evil pruning is had recourse to. A. cuts off the upper limbs, B. prefers the lower, while C. is satisfied with nothing less than the whole. What they would do if they considered well the nature of plants would be—nothing at all, except stopping or breaking back a few laterals while in a growing state. When branches are removed much of the vigour of a tree is removed too, its power of growth is more or less impaired, and the operation defeats the object it is intended to serve. But when branches are merely stopped no loss is incurred; all that happens is that growth ceases in the direction of the stoppage, and the sap which would have been expended in forming the shoots whose growth is arrested is impelled into other shoots, or, more correctly, into that one which is intended for a leader. But as this is impossible in large plantations, and not very practicable anywhere, rival leaders will be found after many weeks' growth; in such cases the removal of a terminal bud will not result in the conveyance of food enough into the selected leader. It then becomes necessary to break the young shoots which are superfluous—to break, not to cut, not to break *off;* the shoot should be simply snapped across, and allowed to hang downwards from the limb, retaining its vitality as long as it can. If the operation is performed skilfully the broken end will remain alive for several weeks. The reason of the practice is this; if a portion of a growing branch is suddenly removed the buds below it are almost certain to break into secondary laterals, and to consume the sap intended for the leader; but if the branch is broken it slowly consumes the sap that reaches it, prevents the buds below from pushing into laterals, and thus

compels all the superfluous sap to travel into the leader where it is wanted.

Nature of herself performs this operation in countries where forests spring up naturally. Multitudes of trees start, self-sown, from the earth; a thicket appears; all lateral shoots perish—they are stopped by the consequences attendant upon want of light and air, and a vast array of poles is the result. By degrees the weakest poles die; spaces are thus cleared in the forests, room is made for the trees which remain, and enables them to develope their heads; long straight timber is the result. But this is a costly process that can scarcely be imitated with advantage.

Pruning then becomes inevitable, and the forester is required to determine how it can be best performed.

No one will deny that the sooner it is performed the better, wounds in young wood healing quickly; and that the longer it is deferred the worse the consequences, the wounds in old wood being large and incurable. The operation may be considered under four different heads—*pruning*, properly so called; *fore-shortening; snagging*, or *lopping;* and *amputating*.

1. *Pruning*.—This is performed upon branches which can be removed by a "draw" or two from the knife of a strong man. It should always be made perpendicularly and close up to the stem whence the branch is removed. The wound thus formed soon disappears, and although the surface of the wound remains as a permanent fault in the timber, yet it is so small as to be of no practical importance. Where stopping is neglected, such pruning is the most unobjectionable substitute, and it must be admitted that on large woodland property it is unavoidable.

Considering the great differences that exist among trees it seems impossible to reduce the art of pruning for timber to anything more than general principles. The Oak grows differently from the Ash, the Beech from the Sycamore, the Scotch Pine from the Larch Fir, and so on. In plants like the Spruce and Larch Mr. Andrew Knight used to remove the lower alternate tiers annually, and eventually all the lowest; but this could not be done with an Elm, whose branches

do not grow in layers. Nevertheless writers on foresting confidently recommend particular methods for everything, an example of which will be found in the following directions given by Gavin Cree, a well-known Scotch forester.

"Were thinning properly attended to, it would do much to accelerate the growth of trees; but in most cases it is neglected. I am of opinion, however, that in addition to thinning, pruning is advantageous in promoting the size and value of timber. Stopping, or breaking off the points of the branches, fulfils, to a certain extent, the purpose of pruning, although I do not think it can so fully accomplish the benefit which pruning will effect. The great object of the forester ought to be to increase the digesting powers of the plant, and thereby administer to its health and vigour. Now I maintain that shortening the branches multiplies the quantity of leaves, and, at the same time, gives greater activity to the sap. A large branch surely puts forth more leaves than a small one, for by shortening, the number of twigs or branches is multiplied almost indefinitely, so that the quantity of foliage, in the aggregate, is far greater on the pruned than on the unpruned plant; while the foliage is more healthful and efficient; presenting leaves as broad as two or three of those on the branches which are of an extravagant length. The principle of stopping and shortening seems to imply a similar design in those who practise the different methods; namely, to keep the branches within due bounds. The difference is, the person who stops them takes no more from the large than from the small branch; whereas the pruner curtails each tier of branches to a uniform length; the tiers extending in breadth as they descend, in the form of a cone. This, at least, is my method. I consider it to be beyond the bounds of human ingenuity to act successfully in this case without some regular system. I shorten the shoot next the top to one half the length of the leader, and allow the lower tier to extend farther than the one above it, till I reach the undermost, which is, of course, the broadest. When the tree is about eighteen feet high, and fifteen inches in circumference, I cut off the lowest tier close to the stem, and continue yearly to cut off a tier (regularly) upwards. I have by this means raised hard wood to as great a height, within the same time, as Larch; and have not discovered, either by observation or otherwise, that trees were ever raised so rapidly to the same altitude, as those trained on the above plan. They sometimes grew ten feet in the course of three years." Mr. Cree says nothing about the unsoundness of timber thus pruned when eighteen feet high.

Better directions are given by an old forester in the *Gardeners' Chronicle*, writing under the name of Philo-Sylva. His words are these:—"The only rule to attend to is to keep the top taper, preserving the leading shoot clear and free from clefts, and the bole from all the

largest branches, leaving those only of the smaller kind that are requi site for the health and support of the tree, and clearing the tree, fro the bottom, of all its branches as it advances in age. But the bo should be cleared *very slowly at first* when the trees are young. Onl keep the branches that are left thereon small *by often pruning*, so a not to injure the tree when it becomes timber. By the heads of tree being kept tapering when young, the rapidity of the growth is greatl increased, on account of the sap being confined to the most usef points, and not allowed to spread in support of large *unnecessar* branches. By attending to these rules, and the operation of prunin being executed *every year*, the bole will be extended to a great heigh and at the end the grand object attained, viz., the production of soun unblemished timber. The proportion which will be found to be mos consistent with full-sized trees is fifty feet trunk to thirty-five feet c head. It is of the utmost importance that trees should have circum ference of stem in suitable proportion to their height. If the circum ference is one inch for every fifteen inches in height, so much th better. Trees should be examined every year till they are fiftee inches in circumference; the highest will then be fully eighteen feet."

2. *Foreshortening.*—This differs from pruning inasmuch a it does not cut back a shoot to its origin, but merely remove one third or half of it, the lower part remaining furnished wit twigs which contribute to the formation of timber. This, whic is advocated by Billington, undoubtedly deserves to form a part of the process of good timber-growing, provided it is s managed that the branch does not die back. Its real objec is to enable leaves to be formed and nevertheless to produc the advantageous effects of pruning. It preserves a latera branch alive for some years, but diminishes its rate of growth so that it may be eventually taken off, having done it work, without inflicting any extensive wound; or it ma preserve a branch alive as long as the tree of which it forms a part continues to exist, and thus enables the forester t remove a limb without injuring the main trunk.

When it is possible to ensure the life of these foreshortene limbs, the method is open to no serious objection; but i practice it is found that such limbs are apt to lose their smal wood and to die, in which case they produce all the mischie that follows snagging or lopping. Sir Joseph Paxton, Prof Henslow, and others have long since shown how likely this i

to occur, and the practice is now employed by first-class foresters only under very special circumstances.

3. *Snagging or Lopping.*—Ignorant woodmen, when called upon to remove a branch, lop it off nearly down to the trunk which produced it. More skilful men cut it off at some distance from the trunk, leaving a spray on it to keep it alive; but the spray is apt to die, and then the more skilful practice becomes undistinguishable from the woodman's lopping. The first is merely a foreshortening, which cannot be made to preserve a permanent effect and fails in its intention. When this happens it is the worst of all known methods of pruning, the effect of which is represented in the accompanying cuts. The knots in deal are well known; when a squared piece of deal is converted into planking, it is sometimes full of knots which drop out as at Fig. LXXXVII. These are sections of dead or dying branches which became imbedded in sound wood in consequence of their having been left by nature in the unpruned, closely-packed natural forest. Had such branches been removed, no faults like these would have been discoverable. They sometimes render deals almost worthless.

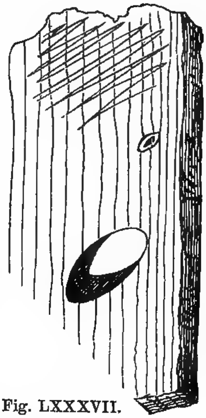

Fig. LXXXVII.

The consequence of leaving snags is exhibited at Fig. LXXXVIII., which fully illustrates the meaning of the following opinions.

"There is a method of pruning," said Mr. Sandys, the skilful and experienced forester at Holkham, "still practised by some persons, of leaving a foot or more of the branch on the tree *to die and rot off*, which if only an inch in diameter may take several years to accomplish, during which time the stem increases, *and when the stump falls down, a hole is left as deep as the tree has grown since the snagging, which hole must have time to fill up after the rotten branch is gone.* The *healing of the wound is consequently delayed, and the defect in the timber greater.* Instead of taking off a large branch by the stem, a great

part of it may be cut off at a distance from it, leaving a small side branch to draw the sap and keep it alive, which is better

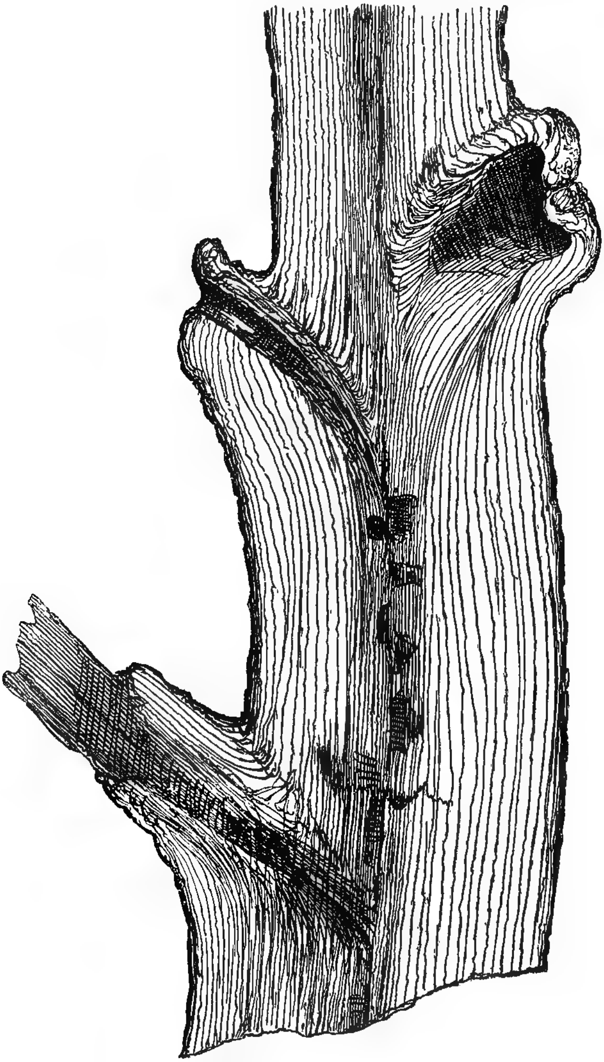

Fig. LXXXVIII.—Consequences of Snagging.

than leaving a snag; but this method should seldom be practised, being only the result of former bad management."

"All scientific planters," wrote Mr. (now Sir Joseph) Paxton, several years since, "are of the same opinion as to the propriety of removing dead or decayed branches. Whenever dead branches are found on any tree, they cannot be too soon removed; and even Fir plantations, which when thickly planted are generally self-pruned, *will be improved* by having all the dead wood pruned off quite close to the stem."

Some years ago, Lord Braybrooke submitted to the examination of Prof. Henslow, than whom no man possesses a sounder judgment, a number of specimens of timber in which the branches had been allowed to die back. The result of that examination, now before me, was as follows:—"In the specimens sent for my inspection, the foreshortened branches were all in a *state of decay*, and where the experiment was pronounced complete, the stumps had become imbedded in new wood which had closed over them, exactly as it does over the surface of the cut produced by close-pruning. Now the only difference between the two results appears to me to be this: that *in the close-pruning we have two clean surfaces, the one of the old and the other of the new wood*, brought into close contact; whilst in the case of the foreshortened branch, *we have the decayed remains of a rotten stump surrounded by an irregular surface of the new wood.*"

4. *Amputating.*—When a branch is broken and dead and requires removal, it should be cut off close to the trunk; but this should never be done if it is possible to avoid it, and it never is necessary except in consequence of previous mismanagement; it is even doubtful whether it can ever be justified. Assuming, however, that it is inevitable, then it is certain that the amputation should be effected by as perpendicular a cut as it is possible to effect. It is an axiom in physiology, that live tissue cannot form an organic union with that which is dead. If in amputations shoots are not removed close to the stem, the remaining part, or snag, dies; and the lips of the wound will not heal; or if the wound is healed externally, either a cavity or a piece of dead wood remains behind. On the other hand, if the branch is cut off close to the trunk, the permanent injury sustained by the tree is a disunion of the tissue for a space equal to the diameter of the

original wound. We must, however, remember that the large wounds produced by the amputation of the limbs of a tree can never be healed, although they may be concealed; so that if the scar left by the process is a foot in diameter, an interruption of the tissue to that extent must always remain, to the destruction of the strength of the timber. By amputation a blemish is necessarily introduced always proportionable to the size of the wound inflicted, that is to say, to the size of the branch removed. In some cases the old wood becomes partially rotten before the new wood closes over the wound; but this more frequently happens when the cut slopes a little outwards from the trunk, and is not quite perpendicular. In the former case, the new wood and bark, which for a time form a sort of collar round the wound, allow the wet to lodge, which thus facilitates decay. But where the wound has been vertical and the cut clean, little or no decay takes place, as is proved by a specimen of Beech which the author has seen, from which a very large limb had been removed, and in which the blemish was of course proportionably great, though the old wood was perfectly sound.

The reason why sloping amputations are followed by rottenness, while perpendicular amputations remain sound, is that rottenness commonly takes place in presence of water, which a sloping wound allows to accumulate, while a perpendicular wound allows no water whatever to lodge. Amputated wood, which is shaved to a smooth surface, will not rot when perpendicular. That is certain. One of the many proofs of this important fact will be seen by referring to the curious example of imbedded letters represented at p. 39, and also by Figures LXXXIX. and XC., which show the consequence of oblique and perpendicular amputation.

Allusion has already (p. 400) been made to leaving young trees very near each other, with a view to imitate nature and to dispense with the necessity for any pruning whatever. Some one says that "thick planting and annual pruning come the nearest possible to the unassisted operation of natural causes," and that all pruning may be resolved into a question of thinning. And this, we believe, is practically followed in some celebrated German forests. There is no doubt that the natural

unpruned forests of Hungary produce trees of the utmost excellence, and that in the north of Germany successful attempts are made to bring about the same result. But much skill, constant supervision, and great practical knowledge of

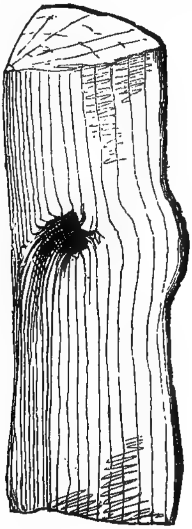

Fig. LXXXIX.

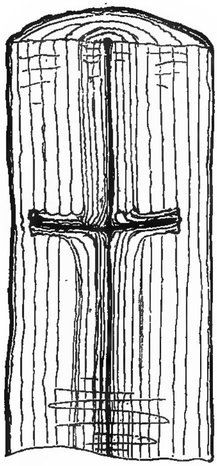

Fig. XC.

vegetable physiology are employed in producing it, such as at the present time certainly does not exist, with a few exceptions, in this country.

Among *concise* directions for managing close plantations advantageously, I have seen none which more deserve attention than the following, given by an experienced correspondent of the *Gardeners' Chronicle*, writing under the name of Philo-Sylva:—

"The value of a timber-tree is much deteriorated by numerous ramifications attracting and retaining a large proportion of the elaborated sap, which, if properly directed by judicious pruning, would go to form valuable timber in the main trunk of the tree. Thinning timeously prevents the necessity of excessive pruning. Thick planting and annual pruning come the nearest possible to the unassisted operations of natural causes towards the formation of straight and well-grown timber. Now, when we find this, which may be considered natural pruning, to produce the straightest and cleanest timber (when this is the object we have in view), ought we not in artificial pruning to attend

to these processes of nature, and endeavour to imitate them as closely as we are able?

"In order to produce the most beneficial effects, the process of pruning should be begun *early*, and not carried to any great extent at once, but renewed every year as the tree advances, until it is brought to the most perfect form its nature will admit of. At this early period the knife is the most suitable implement, *and the top is the principal part which requires attention.* In order that only one shoot may be allowed to remain as a leader, the others next in size, if not very inferior, should be headed down generally to about one half the length, and all the stout branches on the tree headed in the same manner. If the tree be stunted, care must be taken to select a leader that is healthy.

"We cannot too strongly reprobate the common error of clearing young trees entirely of the side branches up to a certain height *at the first pruning*, and afterwards to operate only on the under branches of the tree. This tends to produce a small trunk, an irregular top, and side branches more vigorous than the leader. When this is practised in exposed places (hedge-rows), not one in a hundred ever becomes a large or valuable tree. It is one great and common error *to cut off in one year* branches to the height perhaps of fourteen feet from a tree not above twenty feet high. When this is done the trees remain nearly stationary, and are often stunted to such a degree as to assume the appearance of old age. Such an excess of amputation destroys the health of the tree, by depriving it of the organs by which a sufficiency of sap is secured, to be afterwards converted into wood.

"It is well known that when the leading shoot is destroyed, the growth of the tree is greatly impaired. It is the danger of losing it which makes wise planters so careful in fencing their plantations. By increasing the number of leading shoots the strength of the nutritious principle is rendered in a great measure ineffectual. To counteract the deviation of a strong vertical tendency from nature's own more perfect forms, and to confine to the production of *one valuable stem* the vegetative power which in a forked tree luxuriates in a multiplicity of branches with comparatively trifling effect, is the main object of the system here advocated. Pruning is only of much advantage when performed *early* in those branches which are apt to bear too great a proportion to the leading branch, thereby modifying the tree, and directing its energies gradually to the top, preserving at the same time a sufficient quantity of foliage.

"By proper pruning trees can stand closer together without requiring to be thinned, and the whole of the branches are enabled to retain their vegetative power and live for any length of time in luxuriant beauty. By a different management we often see trees thus reduced to the appearance of so many tufted poles, presenting no obstruction to the

winds which sweep through the plantation, and render the ground so hard that the trees in consequence become unhealthy. But by this method the green branches preserve moisture in the earth to make them healthy, and to arrive *at great magnitude.* Provided we use proper caution in pruning, and do not cut very large branches, it is not of very material consequence what season we choose for the operation; and the smaller wounds caused by the prudent and gradual pruning above recommended will heal in a reasonable time and without any great damage at any season of the year.

"Where hedge-row trees and trees in open situations are intended for profitable timber, pruning should commence at an early period of their growth, encouraging the leading or main stem by displacing or foreshortening all over-luxuriant or aspiring side-shoots, by ripping off buds likely to contend with the leader, *gradually* clearing the lower part of the stem or side-shoots, and forming the top into the shape of a very open cone; that cone, while the trees are under ten years of age, occupying nearly half the length of the tree, and generally diminishing from that proportion as the tree advances, till eventually, when about thirty years of age the tree will have acquired sufficient length of stem, the cone or top may occupy from a third to a fourth part of the whole length. *All lower branches should be removed before they exceed an inch in diameter.* Trees thus managed will form close and healthy stems *without any interior blemish,* and be trained to any reasonable altitude, according to the soil, subsoil, and situation on which they grow; but if neglected, such is the propensity of most sorts of what are called 'round-headed trees,' in open spaces, to run into branches, that without due attention the foliage will become too voluminous for the roots, and a check to loftiness and the formation of useful timber will ensue."

To trust to close planting and to disregard thinning under the idea that nature-pruning is all that trees require is one of the great errors into which inexperienced persons fall. The evil consequences attendant upon such a course are shown by such examples as the following sent to me some years ago by Mr. Hamerton, of Hellifield Peel. "The two following transverse sections as nearly as possible resemble the originals, one of which is taken from a tree of my own growth, and the other from a crowded plantation of about 1000 acres, which it gave me very great pain to view. The one is pro-

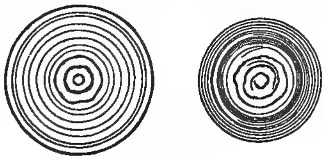

Fig. XCI.

gressively advancing to maturity; the other retrograding, dying year by year—the diminution of its concentric rings proving to demonstration that it has not room to grow."

Upon this subject the reader may consult a paper by Mr. Gosse, in the *Transactions of the Society of Arts*, vol. xlviii. p. 214.

In this case it is sufficiently evident, that in the right-hand specimen the growth was at first, when the trees did not choke each other, fully as rapid as in that on the left, when they continued to be properly thinned; but after the third year, the formation of timber in the former case began to be arrested, and was immediately after reduced to a minimum quantity; while in the latter it continued to form, with little variation, year by year.

The same friendly hand also furnished a specimen of Spruce-fir from an estate in his neighbourhood, in which reliance had been placed upon crowding as a substitute for careful tending. The rates of growth were as follows.

In the first five	years	the tree grew	26-10ths	of an inch in diameter.
Second	,,	,,	24	,,
Third	,,	,,	20	,,
Fourth	,,	,,	12	,,
Fifth	,,	,,	8	,,
Sixth	,,	,,	6	,,
Seventh	,,	,,	10	,,

Here, in thirty-five years, the tree only acquired a diameter of ten inches and a half, the annual formation of timber beginning to diminish after the fifth year, more rapidly after the fifteenth, as the trees became more and more crowded together; and it was only after the thirtieth year, at which time the increase in diameter had been reduced from more than five-tenths to little more than one-tenth of an inch annually, that the formation of timber began to be restored, and this, which was apparently owing to some accidental clearing, only in a slight and very unequal degree; for, from the section it appeared that, although on one side an inch of increase in diameter took place in five years, yet over the principal part of the circumference not more than *two-tenths of*

an inch of timber were formed in five years. Had this tree been properly treated, it ought, by the end of thirty-five years, to have been eighteen inches in diameter, instead of ten inches and a half.

But, bad as are the consequences of a crowded growth to the formation of timber, and also to its quality, it is not the only evil. Plantations which have been crowded for many years cannot afterwards be thinned successfully. The trees become bark-bound and rootless, and are blown over by the first storm. Roots, like timber, are formed in proportion to the quantity of foliage, and to the space a tree has to grow in. A tree whose trunk is divided into limbs, loaded with healthy leaves, fixes itself to the soil by gigantic roots, which hold it immoveably, and help it to defy the storm. But a tree drawn up to a pole, with a few limbs at the summit, has neither the means of forming roots, nor the space in which to develope them. A few fibres are all that it produces, bearing no due proportion to the head; and the moment the protection of the trees around it is withdrawn, it necessarily falls over.

As to the manner of thinning plantations, it does not appear possible to give particular rules for such an operation. Instead, therefore, of saying that when a tree is of such a height it ought to be at such a distance from those around it, it seems better to state as a general rule, that no one tree should be permitted to touch another, but that they should be allowed to remain as close as circumstances will permit, provided their branches do not touch. Practically, it is impossible to adjust the thinning of a plantation with much exactness; and in the annual removal of such trees as are touching others, spaces larger than are actually requisite, according to this rule, will be formed. This is, however, an advantage, because it allows the wind to find its way freely among the trees, and give them sufficient room to spread their roots about.

The planter should be careful to mark during summer the trees that are to be removed in winter; because it is only at the former season, when trees are covered with leaves, that it is possible to ascertain in what degree deciduous trees really interfere with each other.

One of the most important objects to be kept in view in timber management, whatever mode of pruning is adopted, is to cause timber to be formed rapidly. This is little known, and indeed is contrary to the opinion of many woodmen; nevertheless it is susceptible of rigorous demonstration.

Most people believe that the slowest-grown timber is the best; we continually hear it said that wood cannot be good because it has been grown fast, and we find writers on foresting following in the same line of assertion. In one place we observe the following passage:—"It is well known that the common Oak in Italy, *where it grows faster than in this country*, is comparatively of short duration; and that the Oak which grows on the mountains of the Highlands of Scotland *is much harder and closer than any produced in England*, though on these mountains it seldom attains one-tenth part of the size of English trees." It would be difficult to collect in the same space more fallacies than are contained in this short paragraph. In the first place Oaks do not grow faster in Italy than in England; the reverse appears to be the truth, as will be seen by reference to a succeeding table, where the greatest rate of growth in Italian Oak is shown to be only 2·72 10ths per annum, some of it not more than 0·76 of a tenth, while in English Oak the growth is in one case as much as *an inch a year.* Secondly, if it were true that Italian Oak grows faster than English Oak, it would not prove that fast-grown Oak is bad; because some Italian, or at least Sardinian, Oak is of excellent quality, and because, moreover, we neither know what is meant by the words "common Oak," nor are we informed under what circumstances of soil, &c., that which is said to be bad may have been produced. A great deal of Italian Oak is Q. pubescens, and of this, whether fast-grown or slow-grown, the quality is always bad. As to Highland Oak; in the absence of positive evidence it is permitted to doubt the statement made respecting it, especially when we call to mind the Oak forests formerly covering at least a part of Inverness-shire—the size of which, as reported by Dr. Walker and Sir T. D. Lauder, indicated anything rather than slow growth.

The author from whom the foregoing paragraph is quoted,

undertakes to prove, upon physiological principles, that fast-grown timber must necessarily be bad. He says that the effect of an improved soil, climate, and situation, is to *expand* the parts of the whole vegetable; that cutting off part of the vegetable above the ground will *expand* those parts that remain; and he illustrates this his notion about timber by reference to Lettuces, Cabbages, Spinage, and other esculents, which he says are softer the faster they grow, and also to Willows, Poplars, Raspberries, &c., which he says are the fastest-growing of all woody plants, and the softest-wooded. Therefore, he continues, "whatever tends to increase the growth of a tree tends likewise to *expand* the vegetable fibre; and whenever the vegetable fibre is *expanded*, the timber must be less hard, and more permeable by air, &c., and of course inferior for all purposes of timber." These speculations are described by another writer as "interesting, ingenious, and philosophical." I must therefore suppose them to have carried conviction to some minds. In truth, however, they are a tissue of absurdity, evincing a total ignorance of the nature of vegetable organization.

All plants consist of one or other of two substances—the one cellular, the other fibro-vascular. The former is composed of roundish cells, the latter of long tubes; both are termed tissue by physiologists. The cellular tissue, or substance, is brittle, has little force of adhesion, and gives to the parts in which it occurs the texture of a mushroom, or of the pith in an Elder bush. On the other hand, fibro-vascular tissue is tough and strong in various degrees, but in all cases much more tough and strong than the cellular; its nature, in a separate state, may be compared to that of hemp, flax, or other vegetable fibres, which are always composed of fibro-vascular substance.

Timber consists of these two tissues intermixed; when it grows fast, it produces a large quantity of fibro-vascular tissue, and but little cellular; when it grows slowly, it is more cellular than fibro-vascular. There is never any expansion of the fibro-vascular parts; all that happens is that the aggregate number of the latter is increased. Thus, suppose a stick an inch in diameter contains 500 tubes; if you make it grow twice as fast,

it will not expand those tubes, but it will add 500 more to its original number in the same period of time. As regards the cells, they may possibly be somewhat larger in plants of a very soft texture when highly cultivated, than when wild, but this is doubtful, and the difference between wild and cultivated esculents principally depends upon the greater quantity of the cells, and especially of the fluid matter contained in them. Expansion, in the sense in which the writer above-mentioned uses the word, has no existence.

Now, the difference between esculent herbs and woody plants consists mainly in this, that the former are composed principally of cellular substance, and the latter of fibro-vascular. Any addition to, not expansion of, the cellular tissue, renders plants more brittle and more succulent, and therefore more fit to eat. But it is most absurd to say that, therefore, any augmentation of the quantity of fibro-vascular tissue will also render plants more brittle; on the contrary, it is an addition of toughness and flexibility, and the only conceivable effect its augmentation can have will be to render timber yet stronger than before.

With regard to Willows, Poplars, and other plants of that character, they are not soft, because they grow fast; for they are just as weak when they grow slowly—and weaker. Their want of strength and durability arises from their being unable to consolidate their tissue by depositing within it matter of lignification. The sap-wood of the Oak is as soft and perishable as Lime-wood, and for the same reason; namely, because that peculiar matter which the Oak deposits in its tissue, and which gives its heart-wood strength, is not separated and deposited in the sapwood.

The fact is, that so far as vegetable physiology is able to throw, of itself, any light upon this curious subject, it would lead to the conclusion that fast-grown timber is tougher than slow-grown, and superior for all purposes of utility.

The reader will be careful to observe, that in making these remarks I intend them to apply only to the same kind of wood *under the same circumstances.* Wood grown fast *in one place* may be worse or better than wood grown slowly *in some others;* but that is a different question.

As to the accuracy of these statements, evidence enough is to

be found by those who look to facts instead of books, and the following is conclusive proof that Oak, at least, is best when fastest grown and worst when slowest grown.

In the highly interesting collection of naval woods which was formed by the late Sir William Symonds, at the Admiralty Offices in Somerset House, there exists an abundance of specimens of Oak-timber whose quality had been ascertained by actual experiment. To this distinguished officer the author was indebted for the opportunity of examining them, and the result of that examination is given in the following table, which shows the annual rate of growth of twenty-three samples of Oak-timber, given in tenths of an inch for the sake of comparison, together with their respective qualities, as ascertained in her Majesty's dockyards :—

Name or Locality.	Annual rate of Growth, computed in tenths of an inch.	Ascertained Quality.
Duke of Wellington's estate	10.	Very good for Plank.
English	6.66	Good for Plank.
Out of Ship "Gibraltar" .	6.44	Good.
Do. do. . .	4.61	Very good.
Sardinian	4.28	Good.
French	4.	Bad.
Styrian, 1st class	3.33	Indifferent and light.
Dantzic, 1st class	2.85	Tolerable for Plank.
Tuscan, Q. ischia	2.72	Good for Plank.
Istrian, 1st class	2.57	Bad.
Polish	2.50	Indifferent.
American Live Oak . . .	2.39	Good.
English, seasoned . . .	2.37	Good.
American White Oak . .	2.15	Bad.
Russian	2.07	Bad.
Hainault	2.	Bad.
Circassian	1.79	Indifferent.
Tuscan	1.33	Good.
East Prussian	1.17	Indifferent.
Podolian	1.17	Bad.
Canadian	1.07	Bad.
Crimea	0.96	Tolerable.
Tuscan, Q. Farnia . . .	0.76	Bad.

I also find, upon looking to evidence of another kind, that the following are the rates of growth of various other specimens of Oak.

Name or Locality.	Annual rate of Growth, computed in tenths of an inch.	Apparent Quality.
Ruins of York Minster . .	7·78	Excellent, hard, and heavy.
Arundel	3.33	Best quality on the Duke of Norfolk's Estate.
Penrhyn, N.W., White Oak	2.50	Inferior.
Do. do. Red Oak .	2.35	Very good.
Wainscot	2.0	Good.
Northumberland	1.81	Good.
Arundel	1.48	Inferior.
Yorkshire	1.43	Tolerably good.
Wainscot	1.25	Average of several specimens, including good and bad.
Moss Oak, Ayrshire . . .	0.99	Light and bad.
Wainscot	0.80	Brittle and bad.

It is to be hoped that the evidence now produced will satisfy the most sceptical person that fast-grown Oak is, both in theory and in fact, greatly superior to that grown slowly. In the first of the foregoing tables the best in quality was from Strathfieldsaye, and grew as much on an average as an inch in diameter annually, and all those others which grew above four-tenths in diameter were of good quality. On the other hand, all the slowest-grown timber in both tables was bad or indifferent. It is true that some of the Navy Oak of bad quality was fast-grown, as the French, Styrian, and Istrian; but this may have been caused by soil or have been owing to the species. There is reason to believe that some kinds of soil will grow Oak fast without furnishing the matter required for hardening the timber, and that some species common in the South and East of Europe, particularly Q. pubescens, the Downy Oak, are never of value as timber. The specimen of

wood marked French, from the dockyards, was very like that of the Downy species.

There is other evidence of incontestable value which ought to satisfy any reasonable man upon this subject.

If the reader will turn to a pamphlet published in the year 1829 by Mr. Withers, of Holt, in Norfolk, a planter of great experience, he will find a considerable body of evidence in support of the statement that fast-grown Oak is the best. The pamphlet was called a *A Letter to Sir Henry Steuart*, and was written for the purpose of doing away with any impression which might have been made by that gentleman when he stated that slow-grown timber is the best. By the evidence of timber-merchants and other persons familiar with the subject, Mr. Withers proved that the very reverse was the case. Mr. John Stenning, of East Grinstead, expresses himself thus:—

"Another very desirable quality which quick-growing timber possesses is, that it is much stronger and tougher than that which grows slow. The one would bend where the other would break. I am convinced that a ship built exclusively of quick-growing timber, and striking against a rock, would be in safety, when one exclusively built of slow-growing timber would fall to pieces: the former, from strength and toughness of the wood, would yield and clear off; and the latter, from the shortness of the grain of the wood, and its consequent tenderness, would break without reaction. I contend, in contradiction to Sir Henry Steuart, that the heart of such timber is very superior, that it is considerably heavier, and must consequently contain more virtue and condition than that which he recommends to the public as the best.

"Independent of the advantage which the quickness in growth gives to the quality of Oak timber, the bark from the same cause possesses an equal if not greater superiority; as the very highest price is given by the London tanners for bark from this county, where the growth, as I have before mentioned, is very rapid compared with its progress in many parts. The bark from such timber is very thick and fleshy, whereas from that which grows slowly it is thin and drossy.

"The only inducement I have to fall in with Sir Henry

Steuart's notions on the quality of timber is, the consideration 'that the strength of work is the decay of trade.'

"Before concluding my remarks, I beg to state that my observations are the result of thirty years' experience; during that period I have superintended the management and growth of Oak timber, have purchased no inconsiderable quantity, and have been a good deal engaged in the conversion and application of it for different purposes; and I can assert, without fear of contradiction from any experienced individual, that *the quicker Oak timber is produced, the better the quality will be.*"

The opinion of Thomas Andrew Knight was to the same effect:—That gentleman's answer to the query put by Lord Glenbervie—"Whether Oaks which grow in poor soils, and slowly, are of a firmer nature and more durable timber than when grown in richer land?"—was as follows:—"No; their timber is more *porous, lighter*, and *less durable.* The heaviest and best Oaks for *all* purposes grow in strong, deep, red loams, where the Oak frequently increases annually more than an inch in diameter. A layer of very porous wood marks the commencement of each year's growth; and when the growth is small, these *porous layers touch each other.* The superior value of the English Oak *depends on its vigorous and rapid growth,* which frequently exceeds that of the Oak imported from the North of Europe in the *ratio of ten to one.*"

And finally, the experiments of Professor Barlow, at Woolwich, quoted by Mr. Withers, all prove exactly the same fact. In one instance, two specimens of Oak were selected; one (No. 1) from a fast-grown tree, and the other (No. 2) from a slow-growing tree. "The former was grown upon a very *strong good soil.* Its age was, he supposed, about sixty years, and it contained from thirty-eight to forty cubic feet of timber. The other (No. 2) was about one hundred and twenty years old, and was grown upon a light soil with gravel about two feet below the surface. This tree contained about eighty cubic feet; but my informant considers that if No. 1 had stood to attain the same age as No. 2, it would have made at least forty feet *more than that tree.*" Professor Barlow gave the following as the result of his examination.

"The two pieces were squared down each to two inches. They were broken on props fifty inches asunder. Their specific gravity, elasticity, and ultimate and comparative strength, were as below:—

	Spec. grav.	Deflected 1-50th of its length with	Broken with	Comparative strength.
No. 1.	903	660 lbs.	999 lbs.	1561
No. 2.	856	414 lbs.	677 lbs.	1058

"No. 1, it appears, is therefore about of medium strength, my mean number being for English Oak 1470. No. 2 is very weak, my weakest specimen being 1205 (see *Essay on Strength of Timber*). We tried, besides, two very choice specimens of English Oak which had been very long in store, and the numbers were,

Spec. grav.	Deflected 1-50th with	Broken with	Comp. str.
748	896 lbs.	1447 lbs.	2261
756	680 lbs.	1304 lbs.	2037

"These again, compared with your weakest piece, show that your No. 1 is about the common run of English Oak."

Another experiment upon strength gave exactly the same result. These are incontrovertible proofs that, *cæteris paribus*, the fastest-grown Oak is the best; and it may be added that all evidence goes to show that what is true of the Oak is true of other trees.

Few remarks are called for as regards the pruning of shrubberies. The knife is only wanted there to thin the branches so as to prevent them from dying from want of light and air, or to shorten them so as to prevent the shrubbery becoming naked at the bottom. Winter is the season in which the operation is best performed; September and October are the worst months, because the buds of pruned shrubs are apt to break after the last of those months, and the young shoots have not time to ripen. Even midsummer pruning will in damp autumns produce the same disadvantageous result. Nevertheless there are those who advocate autumn pruning for all Evergreens. It is alleged that when Evergreens are cut back in the autumn, the roots, which are not affected by the pruning, continue to absorb during the whole winter, and to render all the mutilated branches turgid with sap against the return of spring; the

consequence of which is, that every bud pushes with great vigour. It is also said that if pruning Evergreens is delayed till the spring, the removal of branches filled with the sap, which would otherwise have been concentrated in the trunk or stock, produces the effect of weakening the tree, and rendering its sprouting thickly less certain. Possibly in mild situations, where there is no danger from severe frost, this mode of reasoning is correct. But it is to be recollected that the greater part of our Evergreens are natives of countries much warmer in summer than our own. The common Laurel is from the Black Sea, the Portugal Laurel from Portugal and Madeira, the Phillyrea from the coast of the Mediterranean, and the Alaternus, Arbutus, Evergreen Oak, and many more, from similar climates. It is true that such trees are sometimes exposed to severe frost; but their winters succeed extremely hot summers, which have the effect of ripening the wood so thoroughly as to render it far more capable of resisting cold than with us under even the most favourable circumstances. It is found in practice in this country that if Evergreens are cut down in the autumn, a hard winter is certain to injure them severely, partly, perhaps, because the natural protection afforded by the leaves to the soil they grow in is removed, and partly, no doubt, because the turgid state to which the naked branches are brought by the influence of the roots, above adverted to, renders the wood more susceptible of cold. It is notorious that a given plant suffers from cold in proportion to the quantity of fluid it contains.

Autumn-pruning Evergreens, then, is disadvantageous in cold climates; for the adverse action by frost is much greater than the favourable effect of the accumulation of sap.

Upon the whole, spring is to be recommended in England for pruning Evergreens. Nowhere are the Laurel hedges more beautiful, or in better order, than at Dropmore; and the practice of Mr. Frost, who has the management of them, entirely supports this opinion. He has had great experience in the matter, and has invariably found the months of March and April most advantageous; indeed, if the weather at the end of March remains severe, he defers the operation till April.

CHAPTER XIV.

OF TRAINING.

Training is one of the most artificial operations that gardeners are acquainted with, its object being to place a plant in a condition to which it could never arrive under ordinary circumstances. It is so nearly connected with the art of pruning, that the French speak of both under the common name of *la taille.* The practice of it forms one of the most complicated parts of horticulture, each species of tree demanding a method peculiar to itself; but the principles on which training depends are few and simple.

Those who desire to understand the routine of training must refer to their garden library. In all works devoted to the art of gardening, full instructions are given for the management of every kind of tree in common cultivation. From Miller's *Dictionary* up to Mackintosh's very useful *Book of the Garden* we find the most minute instructions how to train a tree; there is wall-training and espalier-training, pyramidal-training and balloon-training, dwarf-training and standard-training, pillar-training, horizontal-training, zigzag-training, and a host of other devices which ingenious persons have invented. Some are necessary, some useful, some fanciful. In matters horticultural there are martinets as well as in matters military; and many a gardener practically falls into the error of supposing that the goose step, a tight jacket, leather stock, and pipe clay, make the soldier. He measures the angles of a tree, pinions its limbs, drills its branches by inexorable rules, "cuts hard in," "lays in close," and then believes he has exhausted skill. The tree looks well perhaps, but a small matter makes it ill, limb

after limb dies away, fruit does not set, and all its spruceness ends in rags and tatters. This comes of neglect of first principles. Not that a gardener should undervalue in the smallest degree the rules which long experience has established; quite the contrary. It is because it is observed without intelligence, and without a thought to first principles, that mere routine, however excellent, is apt to lead to failure. And it may be asserted with perfect truth that in training fruit-trees, it is better to understand principles and to be ignorant of rules of practice, than to be familiar with the latter and unacquainted with the former. In this place principles only have to be adverted to.

It is probable that the intention of the first gardener who trained a tree was to gain some advantage of climate, by availing himself of a wall or other screen; and this is still one of our greatest objects; partly with a view to guard the flowers in spring from cold, and especially cold winds, partly to expose the leaves and fruit to a hotter temperature than would otherwise be gained, and in some measure to ripen wood with more certainty.

That training a tree over the face of a wall will protect the blossoms from cold must be apparent, when we consider the severe effect of excessive evaporation upon the tender parts; a merely low temperature will produce but little comparative injury in a still air, because the more essential parts of the flower are very much guarded by the bracts, calyx, and petals, which overlie them, and, moreover, because radiation will be intercepted by the branches themselves placed one above the other, so that none but the uppermost branches which radiate into space will feel its full effects; but, when a cold wind is constantly passing through the branches and among the flowers, the perspiration, against which no sufficient guard is provided by nature, becomes so rapid as to increase the amount of cold considerably, besides abstracting more aqueous matter than a plant can safely part with. To prevent this being one of the great objects of training trees, it is inconceivable how any one should have recommended such devices as those mentioned in the *Horticultural Transactions*, ii. Appendix, p. 8., of

training trees upon a horizontal plane; the only effect of which would be to expose a tree as much as possible to the effect of that radiation which it is the very purpose of training to guard against.

The actual temperature to which a tree trained upon a wall facing the sun is exposed is much higher than that of the surrounding air, not only because it receives a larger amount of the direct solar rays, but because of the heat received by the surrounding earth, reflected from it and absorbed by the wall itself. Under such circumstances the secretions of the plant are more fully elaborated than in a more shady and colder situation; and, by aid of the greater heat and dryness in front of a south wall, the period of maturity is much advanced. In this way we succeed in procuring a Mediterranean or Persian summer in these northern latitudes. When the excellence of fruit depends upon its sweetness, the quality is exceedingly improved by such an exposure to the sun; for it is found that the quantity of sugar elaborated in a fruit is obtained by an alteration of the gummy, mucilaginous, and gelatinous matters previously formed in it, and the quantity of those matters will be in proportion to the amount of light to which the tree, if healthy, has been exposed. Hence the greater sweetness of Plums, Pears, &c., raised on walls from those grown on standards. It has been already stated that an increase of heat has been sought for on walls by blackening them; and we are assured in the *Horticultural Transactions* (iii. 330) that, in the cultivation of the Grape, this has been attended with the best effects. But, unless when trees are young, the wall ought to be covered with foliage during summer, and the blackened surface would scarcely act; and in the spring the expansion of the flowers would be hastened by it, which is no advantage in cold late springs, because of the greater liability of early flowers to perish from cold. That a blackened surface does produce a beneficial effect upon trees trained over it is, however, probable, although not by hastening the maturation of fruit; it is by raising the temperature of the wall in autumn when the leaves are falling, and the darkened surface becomes uncovered, that the advantages are perceived by a better com-

pletion of the process of growth, the result of which is the ripening the wood. This is, indeed, the view taken of it by Mr. Harrison, who found the practice necessary, in order to obtain crops of Pears in late seasons at Wortley, in Yorkshire (see *Hort. Trans.*, iii. 330, and vi. 453). It hardly need be added that the effect of blackening will be in proportion to the thinness of the training, and *vice versâ.*

Another object of training is, to place a tree in such a state of constraint that its juices are unable to circulate freely, the result of which is exactly that already assigned to the process of ringing (see p. 370). If a stem is trained erect it is more vigorous than if placed in any other position, and its tendency to bear leaves rather than flowers is increased; in proportion as it deviates from the perpendicular is its vigour diminished. For instance, if a stem is headed back, and only two opposite buds are allowed to grow, they continue to push equally, so long as their relation to the perpendicular is the same; but, if one is bent towards a horizontal direction, and the other allowed to remain, the growth of the former is immediately checked; let the depression be increased, the weakness of the branch increases proportionally; and this may be carried on till the branch perishes by a process of abstracting food analogous to starvation in animals. In training, this fact is of the utmost value in enabling the gardener to regulate the symmetry of a tree, and to cause one part to balance another exactly, which is one of the first objects the trainer has to attain. Whenever one branch or one side of a trained tree becomes stronger than another, the difference increases till the larger succeeds in starving the former. It however by no means follows that, because out of two contiguous branches, one growing erect and the other forced into a downward direction, the latter may die, that if all branches are trained downwards any will die. On the contrary, a general inversion of their natural position is of so little consequence to their healthiness, that no effect seems in general to be produced beyond that of causing a slow circulation, and the formation of flowers. Hence the directing of branches downwards is one of the commonest and most successful contrivances employed by gardeners to

render plants fruitful. Mr. Knight was the first to recommend the practice, in the following account of his recovery of an old and worthless Pear-tree.

"An old St. Germain Pear-tree, of the spurious kind, had been trained in the fan form, against a north-west wall in my garden, and the central branches, as usually happens in old trees thus trained, had long reached the top of the wall, and had become wholly unproductive. The other branches afforded but very little fruit, and that never acquiring maturity was consequently of no value; so that it was necessary to change the variety, as well as to render the tree productive. To attain these purposes, every branch which did not want at least twenty degrees of being perpendicular was taken out at its base; and the spurs upon every other branch, which I intended to retain, were taken off closely with the saw and chisel. Into these branches, at their subdivisions, grafts were inserted at different distances from the root, and some so near the extremities of the branches, that the tree extended as widely in the autumn after it was grafted, as it did in the preceding year. The grafts were also so disposed, that every part of the space the tree previously covered was equally well supplied with young wood.

"As soon, in the succeeding summer, as the young shoots had attained sufficient length, they were trained almost perpendicularly downwards, between the larger branches and the wall, to which they were nailed. The most perpendicular remaining branch upon each side was grafted about four feet below the top of the wall, which is twelve feet high; and the young shoots, which the grafts upon these afforded, were trained inwards, and bent down to occupy the space from which the old central branches had been taken away; and therefore very little vacant space remained any where in the end of the first autumn. A few blossoms, but not any fruit, were produced by several of the grafts in the succeeding spring; but in the following year, and subsequently, I have had abundant crops, equally dispersed over every part of the tree; and I have scarcely ever seen such an exuberance of blossom as this tree presents in the present spring." (*Hort. Trans.*, ii. 78.)

The practice was then followed by Sir Joseph Banks, whose fruit-trees trained downwards over the walls of his garden at Spring Grove, and facing the high road, long excited the astonishment of passers by; and it has now been generally applied to other cases. What are called Balloon Apples and Pears, formed by forcing downwards all the branches of

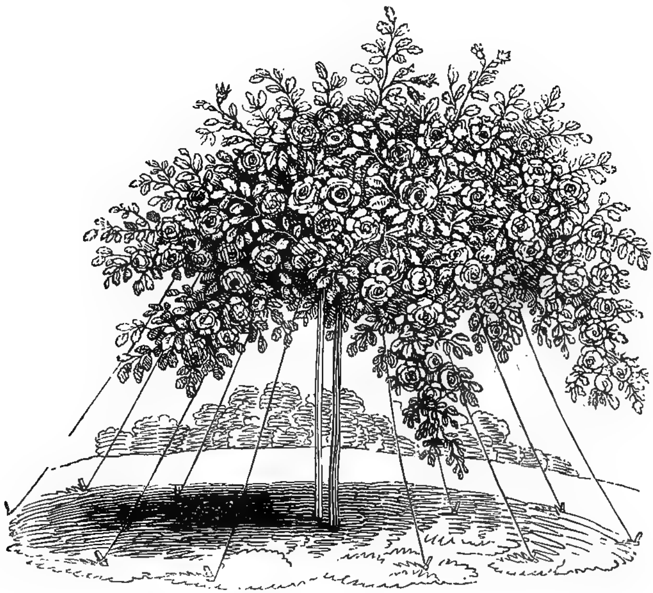

Fig. XCII.

standard trees till the points touch the earth, are an instance of this; and they have the merit of producing large crops of fruit in a very small compass: their upper parts are, however, too much exposed to radiation at night, and the crop from that part of the branches is apt to be cut off. One of the prettiest applications of this principle is that of Mr. Charles Lawrence, described in the *Gardeners' Magazine*, viii. 680, by means of which standard Rose-trees are converted into masses of flowers. The figure given in that work, and here reproduced (Fig. XCII.), represents the variety called the Bizarre de la

Chine, "which flowered most abundantly to the ends of its branches, and was truly a splendid object."

All roses will not however submit to this process; it is only the free-growing kinds, such as those having a little alpine or Chinese blood in them or bred from the Damask and Provence Roses that really look well. The Gallicas and short-branched sorts in general are unfit for the operation; which, when well performed upon such sorts as the Coupe d'Hébé for example, produces plants unsurpassed for beauty by any ornament of the flower garden. This training should always be performed in mid-winter, when there is little sap in the branches. If delayed till the sap flows in the spring, the branches become brittle, and break instead of bending.

The last object of training to which it is necessary to advert is that of improving the quality of fruit, by compelling the sap to travel to a very considerable distance. The earliest notice of this, with which I am acquainted, is the following by Mr. Williams of Pitmaston.

"Within a few years past," he says in 1818, "I have gradually trained bearing branches of a small Black Cluster Grape, to the distance of near fifty feet from the root, and I find the branches every year grow larger, and ripen earlier as the shoots continue to advance. According to Mr. Knight's theory of the circulation of the sap, the ascending sap must necessarily become enriched by the nutritious particles it meets with in its progress through the vessels of the alburnum; the wood at the top of tall trees, therefore, becomes short-jointed and full of blossom-buds, and the fruit there situated attains its greatest perfection. Hence we find Pine and Fir-trees loaded with the finest cones on the top boughs; the largest acorns grow on the terminal branches of the Oak, and the finest mast on the high boughs of the Beech and Chestnut; so likewise Apples, Pears, Cherries, &c., are always best flavoured from the top of the tree." (*Hort. Trans.*, iii. 250, 251.) The merit of the Fontainebleau mode of training the Vine (Fig. XCIII.), in which many of the stems are carried to very considerable distances, seems to depend in some measure upon this principle; and there is a well-known Black Hamburgh

Grape at Bath, growing in a garden formerly belonging to Mr. Farrant, the stem of which, owing to local circumstances, is necessarily conveyed to a very considerable distance before it is allowed to produce its bearing branches, the quality of whose fruit is of very unusual excellence. These facts seem capable of being applied to many important improvements in fruit management.

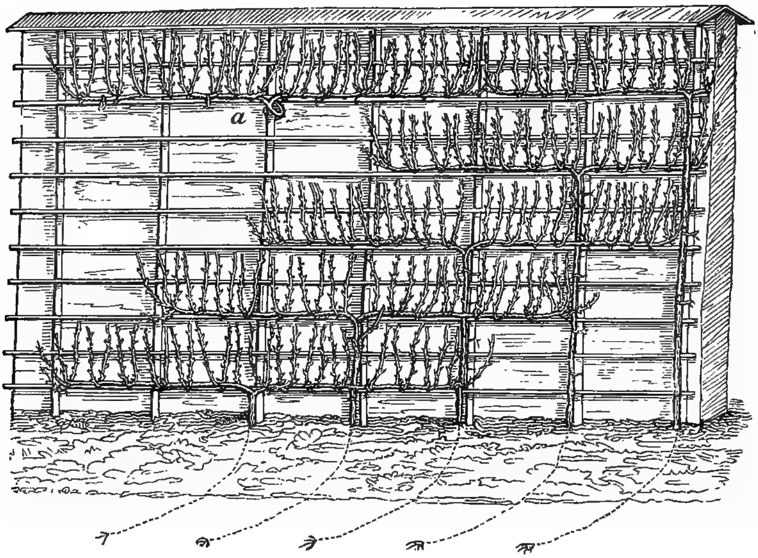

Fig. XCIII.—Vine-training at Fontainebleau.

The foregoing are the principal advantages which arise from training plants; let us next consider what disadvantages there may be. The only trees which at all approach in nature the state of trained plants are climbers and creepers, whose stems, unable to support themselves, cling for a prop upon whatever they are near; some of them enclose the stem of another plant in their convolutions; others simply attach themselves by means of tendrils as the Vine, by hooks as the Combretum, or by other contrivances; and some, like the Ivy, lay hold of walls, rocks, or the trunks of trees, by their rootlets. To none

of these can that motion be necessary to which some plants are naturally exposed, and which, as has been already seen, is of so much importance to the healthy maintenance of their functions. Hence it is, that among fruit-trees the Vine never suffers from being trained: indeed its anatomical structure is specially suited to such a mode of existence; while all erect trees, of whatever kind, whose branches nature intended to be rocked by the storm, and perpetually waved by the currents of air to which they are exposed, in all cases suffer more or less.

One of the commonest and worst diseases induced by training is a gradual impermeability of tissue to the free passage of sap, which appears to stagnate, so that in time the branches become debilitated and juiceless: the obstruction to the flow of the sap tends to produce coarse shoots from various parts of the branches, and especially from the roots. The cause of this seems to be the too rapid deposit of the matter of lignification, and to be induced by want of motion and excessive exposure of the leaves and branches to the sun. The effect of the latter is to inspissate all the juices, and to promote their formation; while the former increases the evil by not keeping the fluids in rapid circulation; just as we know that a slow stream from a muddy source deposits its impurities much more copiously than a rapid stream. As this evil arises out of the operation of training, and seems to be inseparable from it, there can be no expectation of a remedy being discovered.

The increase of the saccharine quality of fruit is by no means an advantage in all cases; it improves the Peach, the Nectarine, the Pear, and the Plum, in which sweetness is the great object: but it deteriorates the Apple and the Apricot, which are chiefly valued for their peculiar mixture of acidity and sweetness.

The protection received in the spring by trees trained upon walls exposed to the sun, while it advances the period of flowering, at the same time causes it to take place at a season when they are not sufficiently secure from spring frosts; and hence the necessity of protecting such plants artificially by coping, screens, bushes, curtains, and other contrivances. It

is on this account that the utility of flued walls is so much diminished, and that they are found, in practice, more valuable for ripening wood in autumn, than for guarding blossoms in the spring.

CHAPTER XV.

OF POTTING.

WHEN a plant is forced to grow in a small earthen vessel like a garden pot, its condition is exceedingly different from that to which it would be naturally exposed. The roots, instead of having the power of spreading constantly outwards, and away from their original starting point, are constrained to grow back upon themselves; the supply of food is comparatively uncertain; and they are usually exposed to fluctuations of temperature and moisture unknown in a natural condition. For these reasons, potted plants are often in worse health than those growing freely in the ground; but, as the operation of potting is one of indispensable necessity, it is for the scientific gardener, firstly, to guard against the injuries sustainable by plants to which the operation must be applied; and, secondly, to avoid, as far as may be possible, exposing them to such an artificial state of existence. That the latter may be done more frequently than is supposed will be sufficiently obvious, when we have considered what the purposes really are that the gardener needs to gain by potting.

The first and greatest end attained by potting is, the power of moving plants about from place to place without injury; greenhouse plants from the open air to the house, and *vice versâ;* hardy species, difficult to transplant, to their final stations in the open ground without disturbing their roots; annuals raised in heat to the open borders; and so on: and, when this power of moving plants is wanted, pots afford the only means of doing so. It also cramps the roots, diminishes the tendency to form leaves, and increases the disposition to

flower. Another object is, to effect a secure and constant drainage from roots of water; a third is, to expose the roots to the most favourable amount of bottom-heat, which cannot be readily accomplished when plants of large size are made to grow in the ground even of a hothouse; and, finally, it is a convenient process for the nourishment of delicate seedlings. Unless some one of these ends is to be answered, and cannot be effected in a more natural manner, potting is better dispensed with.

Many suggestions have been made with a view to improve the construction of the common garden-pot. The following deserve to be recorded. One is a contrivance by Mr. Fry, of Blackheath, for examining the roots of plants in very large pots. It is not possible to take the "ball" out of such pots by the usual process of inverting them, and allowing the ball to drop, because they are too heavy. Mr. Fry meets the difficulty by the following contrivance. A pot is made with a moveable bottom, concave on the upper side like a saucer. When the ball of such a pot is to be examined, the latter is placed upon a heavy wooden block cut into a cylindrical form, which forces upwards the moveable bottom, and carries the ball with it without the slightest disturbance. After the roots have been examined, the pot is lifted upwards till the ball is replaced, and the wooden cylinder is removed. Mr. Beaton proposes to do away with the hole at the bottom altogether; and, instead of the flat bottom, the maker elevates the centre of it, like the bottom of a common black bottle; drainage-holes being round the sides at the bottom. From two to six holes, according to the size of the pot, are sufficient. "The roots cannot get through the bottom, neither can the worms get in, and water cannot hang under the pot in winter." Another proposal is, that when plants are intended for bedding out, they should first be put into pots having both ends open, and that the seeds should be sown on the broad end, which is kept uppermost.

That potting may be dispensed with in many cases, is evident from several facts more or less well known. The nurserymen prefer "pricking out" their delicate seedlings into pans, or moveable borders, instead of pots; and they always thrive the better. In conservatories, the necessity of shifting plants from place to place may be often avoided; while, under judicious management, those which are planted in the open soil have greatly the advantage of others, both in healthiness and easiness of management; and it is found that Pine-apples

succeed better unpotted, if planted freely in soil exposed to a *proper amount of bottom-heat.* This was first asserted by Mr. Martin Call, one of the Emperor's gardeners at St. Petersburg (*Hort. Trans.*, iv. 471), and has been since practised very successfully by others. In the year 1830, a Pine-apple, obtained by this treatment, weighing 9 lb. 4 oz., was sent to the King of England by Mr. Edwards, of Rheola; and in modern practice all great Pine growers adopt this plan when circumstances permit them to do so. (See *A Treatise on the Hamiltonian System of Cultivating the Pine Apple.* By Joseph Hamilton. Ed. 2, London, 1845.)

The exhaustion of soil by a plant is one of the most obvious inconveniences of potting. The nutrient matter in a soluble state, contained in a garden pot, must necessarily be soon consumed by the numerous roots crowded into a narrow compass and continually feeding upon it. The effects of this are seen in the smallness of leaves, the weakness of branches, the fewness and imperfect condition of flowers, &c.; and the gardener remedies them by applying liquid manure, by frequent shifting, or by placing his plants in *pan-feeders*, shallow earthen vessels containing manure, to which the roots have access through the holes in the bottom of a pot. It is, however, to shifting more particularly, that recourse is had for renovating the soil; and this, if skilfully performed, without giving a sudden and violent shock to the plant, is probably the best means; because the roots are thus allowed more liberty of distribution, and the earth is kept more permeable than when consolidated by repeated applications of liquid manure. There is, however, a difficulty in shifting plants without injury to their roots, in the midst of full vegetation; and at such times the application of liquid manure is preferable when the soil requires renovation.

Every one knows that the soil of a farm will not bear, year after year, the same kind of crop, but that one kind of produce is cultivated on a piece of ground one year, and is succeeded by some other kind; which practice, in part, constitutes the important system of rotation of crops. Not, however, to refer to matters extra-horticultural, it is notorious that an Apple orchard will not immediately succeed upon the site of an old

orchard of the same kind of fruit; a wall-border, in which fruit-trees have been long grown, becomes at last insensible to manure, and requires to be renewed; and, not to dwell upon an undisputed fact, Dahlias do not "like" the soil in which Dahlias were grown the previous year. What is the real cause of this? Not exhaustion of ordinary fertilising ingredients because that exhaustion is made good and yet to no purpose Are we to assume, what seems to be the fact, that land contains something mineral which each species prefers to feed on, and which is not contained in ordinary manure? This will be further considered in the final chapter on soil and manure.

It is not, however, merely for the purpose of removing deteriorated earth or adding manure, that shifting is important in all potted plants the ball of earth, by the continual passage of water through it, is in time reduced to a state of hardness and solidity unfavourable to the retention of moisture or the growth of roots, and this is of course cured if the operation of shifting is judiciously performed. I must, however, confess I *have* seen gardeners contented with lifting a plant with a hard old matted ball, out of one pot into another of a little larger size, shaking some particles of fresh earth in between the ball and the side of the pot, and pressing the whole down with as much force as the thumbs can give. Do such men deserve the name of Gardeners?

It is found that the roots of potted plants invariably direct themselves towards the sides of the pot, as must indeed necessarily happen in consequence of their disposition to grow horizontally. Having reached the sides, they do not turn back, but follow the earthenware surface, till at last they form an entangled stratum enclosing a ball of earth; then, if not relieved by repotting, they rise upwards towards the surface, or they attempt to force themselves back to the centre. The greater number of roots are, however, always found in contact with the porous earthen sides of the vessel; and especially all the most powerfully absorbent, that is to say the youngest parts. They are, therefore, in contact with a body subject to great variations of temperature and moisture, in consequence of exposure to the sun, or to a dry air in motion, unless in

those cases where the air is kept, by artificial means, shaded and uniformly damp. The extent of these changes gardeners are hardly aware of; a few years ago I found in a conservatory, in the months of May and June, that the temperature of the soil in a small flower-pot was as low as 40° at one period of the day and as high as 90° at another period. In a dry summer day, when the leaves are perspiring freely and requiring an abundance of water from the roots, the latter are placed in contact with a substance whose moisture is continually diminishing; or in a greenhouse, where the pots are syringed, the heat of the earth in contact with the roots is lowered by a copious evaporation from the sides of the pot, just when, in nature, the bottom-heat should be the greatest. The evil consequences of this are well known to gardeners, who however often neglect taking sufficient precautions to prevent it. Greenhouse plants exposed to the open air in summer always suffer severely from the irregular condition of the sides of the pots, whence the common practice of plunging them in the earth, for the purpose of bringing them into the condition of plants growing in the open ground.

This is, however, attended with some disadvantage, for the plants root, through the bottom of the pots or over the edges, among the earth in which they are plunged, and when taken up in the autumn for removal they must have all such roots cut off again, for there are no means of bringing them within the limits of a pot. For these and similar reasons, no good gardener will expose his greenhouse plants to the open air in summer, *if he can help it*, unless they are duplicates, or unless there is some object to be attained very different from the strange notion that they are rendered more hardy by the process. The effect that is really produced upon them is to give them a sort of artificial winter in summer, that is to say to expose them to a period of comparative rest from growth, which in many cases is useful, or to expose them more fully to the sun at a time when they are ripening fruit. Mr. Knight assures us that by having the sides of their pots exposed fully to the air, the taste and flavour of the Peach and Nectarine, and still more of the Strawberry, are greatly improved, and the Fig-tree in the stove is made to

afford a longer succession of produce, owing to the succession of young shoots which are caused to spring from its larger branches and stems; and, in all cases *when trees can be made to retain their health* in exposed pots, the period of the maturity of their fruit is very considerably accelerated." (*Hort. Trans.*, vii. 258.) This seems to have led Mr. Rivers to his happy idea of orchard-houses and miniature fruit-gardens, now so much in request.

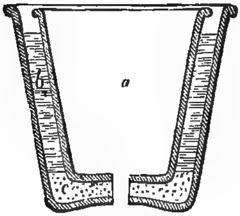

Fig. XCIV.

The best method of counteracting the injurious effects of exposure to the air is by employing double pots (Fig. XCIV.), as recommended in the *Gardeners' Magazine*, ix. 576, and by Captain Mangles in his *Floral Calendar*, p. 44; the space (*b*) between the two pots being filled up with moss or any other substance retentive of moisture.

There are two ingenious contrivances of this nature: one by Mr. Robert Brown, potter, at Ewell, and the other by Mr. William Rendle, the nurseryman at Plymouth. In both cases the object is the same, namely, to have a double-sided pot in one piece. It is obvious that by such contrivances, if the sides of a pot are left empty, the stratum of air contained between them will prevent the earth from becoming heated; and if they are filled with water, the inconvenience of over-watering, on the one hand, or over-drying, on the other, will be prevented in summer, because water will be continually filtering slowly through the inside lining as the roots require it. The latter reason renders them valuable for striking cuttings, and for window gardens, where it is almost impossible to keep plants duly supplied with moisture. Doubtless, in winter, if water be introduced between the sides of this kind of pot, its inner surface will be always *wet;* the young roots will receive too much fluid, and the plant will die: but if the empty space be permitted to remain empty, the inner portion of the pot receiving moisture only from the watering required for the well-being of the plant, the outer side having water occasionally poured on it, or the pot being immersed for a few minutes in it, the sides of the pot will be kept so fully saturated, that they will be constantly giving out into the empty space a vapour, by which the inner portion of the innermost pot (towards which the young roots always incline, and with which they are in contact) will be kept sufficiently cool and moist, and the roots will be preserved from injury."

Of Rendle's pots (Fig. XCV., *a* and *b*), *a* differs in no material degree from Brown's, except that its lower angles are made stronger, and it is better contrived for drainage; the other (*b*, which was proposed for striking cuttings) has a central hollow space which enables

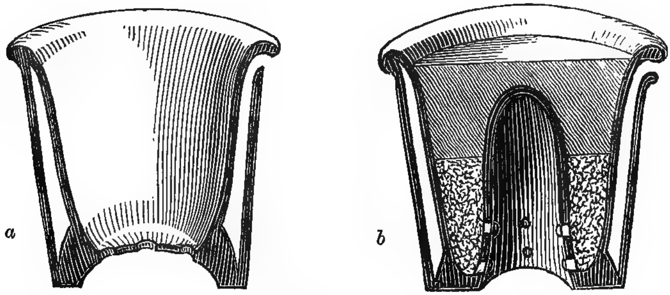

Fig. XCV.

the bottom-heat to be better maintained. Neither of the plans seem, however, to have found favour among gardeners, probably on account of the expense; indeed, it is manifest that three common pots of unequal size can be readily so arranged as to produce all the effect of even Rendle's second sort.

Of course the inconveniences thus described are principally sustained by plants in small pots. When the quantity of earth is considerable, as in tubs or the largest kind of pots, the loss of water through the sides is of little moment, and the variation of temperature is more than counteracted by the large surface exposed to the direct influence of the solar rays. In these, as in all other cases, perfect drainage is of the greatest service, and should be carefully secured by placing an abundance of broken tiles, potsherds, &c., in the bottom of a pot, so as to prevent the stagnation of water about the roots.

Mr. Macnab, in his excellent practical treatise upon the cultivation of Cape Heaths, points out very forcibly the value of good draining to that class of plants. There is scarcely any danger, he says, of giving too much draining; and, in order to effect this essential object still more perfectly, he, in shifting his Heaths, constantly keeps the centre elevated above the general level of the earth in the pot or tub, so that at last each plant stands on the summit of a small hillock.

In order to counteract the risk of excessive drainage, without in reality diminishing it, great advantage is derived from the introduction into the earth of fragments of some absorbent stone. Mr. Macnab uses "coarse soft free-stone broken into pieces from one inch to four or five inches in diameter;" because in summer these stones retain moisture longer than the earth, and in winter allow a free circulation of any superabundant moisture.

The mode of effecting drainage practically is thus described by Mr. W. Moody, an experienced correspondent of the *Gardeners' Chronicle*:—

"The materials for this purpose should be perfectly dry and free from dust, whether they be crocks, charcoal, or sandstone; they should be broken into different sizes, each size being placed separately; thus, if I were using 3-inch pots, I first clean the pot well inside if required, then place a piece of crock at the bottom, nearly as large as will cover it, but convex, so as to allow the water free egress; on this I place a layer of broken crocks, or other material, about the size of Beans, and on this again a slight layer about the size of Peas. When I use pots of a larger size, I use larger pieces, always keeping the coarsest at the bottom and the smallest at the top. With very few exceptions, the plants will be benefited by placing a thin layer of turfy loam or peat over the drainage, as this keeps the smaller particles of earth from being carried downwards. Although there is no fear of drainage being impaired, if properly constructed, yet, to make doubly sure, let each pot be crocked as regularly as possible, one having no more drainage than another, so that in the next shift each may get the same proportion of soil as well as drainage. Pieces of sandstone mixed with the soil are very useful in drainage for hard-wooded plants, as are also pieces of charcoal and bone-dust for soft-wooded ones; in either case the roots will be found closely adhering to these lumps. There are many gardeners who say, 'I have no time to attend to such a routine of breaking and layering;' but crocks do not spoil by being broken and sorted in the coldest day in winter, nor yet if done in wet weather, when nothing can be done out of doors. The different sizes may be placed in large pots, and put somewhere out of the way, where they will be dry until the crocks are wanted for use, which is generally in spring and summer seasons, when work is pressing; thus time is saved by having crocks previously prepared, and plants are benefited by judiciously arranged drainage, which is sure to be effectual." This advice is selected from among many others, because it seems to describe the best kind of practice in the fewest words. Another, and very good method, is the following:—

"The ordinary way of putting at the bottom of the pot a large

quantity of crocks is but a clumsy proceeding, and one which, if it affords an opportunity for roots to spread themselves freely, affords also a harbour for worms, slugs, woodlice, and other vermin. To remedy this, I put at the bottom a piece of perforated zinc, an inch and a quarter, or more, square, according to the size of the pot, so as completely to cover the hole; this perforated zinc may be had for a trifle of any brazier or tin-plate worker, and may, by the help of a strong pair of scissors or small shears, be readily cut to the requisite size; upon this I place a small potsherd, with its convex side upwards, taking care that by resting partly upon the zinc it renders it immovable. I then put in a quantity of good moss so as to form a layer of a third of an inch, or more, thick, when pressed together by the mould, and proceed to finish as usual the operation of potting the plant. I have found this method to succeed perfectly: constant drainage is effected; the moss, particularly with the addition of the potsherd, prevents the earth from choking the holes of the zinc, and by partial decomposition, where it is in contact with the soil, affords an agreeable receptacle for the roots of the plant, in which they appear to delight. All sorts of vermin are excluded; the operation of shifting is facilitated, as the earth comes out of the pot unbroken; and it is, moreover, a much more cleanly process than the one commonly used. I must, however, add, that if the pots thus treated are placed out of doors, it will still be desirable that they should be put upon tiles or slates, or something of the sort; because, as the compost is generally rich, the worms will be attracted by the water which drains from it, and although they cannot get into the pot, if the bottom, inside, be level so as to keep the zinc close all round, they will fill the hole below it with their casts, and thus impede the drainage."

Materials for drainage abound among the refuse of all gardens. Broken pots, called crocks, are usually employed, and, if not burnt too hard, are amongst the more useful. It is, however, of considerable importance that the material, be it what it may, should be soft and porous. Burnt clay, pounded bricks, fragments of charcoal, all which, by virtue of their porosity, retain gaseous matters, are among the best, inasmuch as they not only drain soil, but feed plants. For the same reason bones, crushed with a hammer into pieces varying in size from that of a hazel nut to a walnut, may perhaps be regarded as the best of all.

If woody plants are allowed to remain growing in the same pot for many years, as is sometimes the case, one of two things must happen: either the roots, matted into a hard ball, become so tortuous and hard as to be unfit for the free passage of sap through them; or they acquire a spiral direction. In

either case, if such plants are turned out of their pots in a conservatory, or in the open ground, with a view to their future growth in a state of liberty, new roots will be made with difficulty, and it will be a long time before the effects of growth in the free soil will be apparent. Where the spiral or cork-screw direction has been once taken by the roots, they are very apt to retain it during the remainder of their lives; and if, when they have become large trees, they are exposed to a gale of wind, they readily blow out of the ground, as was continually happening with the Pinasters some years ago, when the nurserymen kept that kind of Fir for sale in pots. In all such cases as these, the roots should be carefully disentangled and straightened at the time when transplantation takes place. To prevent the possibility of this occurrence it is not unusual to place trees intended for transplantation in old baskets. Through their wicker sides the roots readily penetrate, and when this has happened, the half decayed baskets are lifted and "potted" in other baskets of a larger size.

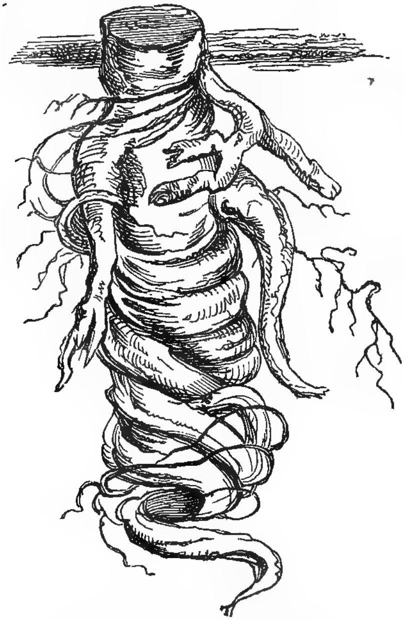

Fig. XCVI.—Root of Pinus Laricio.

The annexed sketch of the root of a Laricio, taken up at Hatfield, by Mr. William Ingram, the gardener there, after having been planted ten years, illustrates the effects of corkscrewing better than any description.

Under ordinary circumstances a potted plant when young, is placed in as small a pot as it will grow in, and is transferred from time to time to larger pots as it advances in size. If this is done,

the warmth to which the pot is exposed is immediately felt by the roots; and the latter, as they grow, ramify regularly through the mass of earth. The practical effect of this is well shown by the Rev. William Williamson, who thus describes his mode of treating the Balsam.

"As soon as they have got four leaves, I transplant them singly into the smallest pots I can procure, and in such a manner that the stem of the plant may be covered somewhat more than it was at first, and then all are to be again placed in the frame. In a short time, if there be a sufficiency of heat, that part of the stem which is covered with the mould puts forth fibres, by which nourishment is conveyed more immediately to the principal stem of the plant. As soon as the plants are a little advanced in growth, they are again removed (if possible without disturbing the earth) into somewhat larger pots, still planting them rather deeper than before. The same process is repeated five or six times, till, at last, they are removed into their final pots. I have found it best to give them their last removal after they have opened their first blossoms, as it gives additional brilliancy and size to the flowers. By following this method the plant acquires extraordinary vigour, throwing out its branches from the surface of the mould, exhibiting flowers nearly as large as a full-blown rose, and a stem measuring two, and sometimes three, inches in circumference." (*Hort. Trans.*, iii. 128.) It must here be borne in mind that the plan of continually sinking the stem with every succeeding potting, although useful to the Balsam, because it puts forth roots in abundance from its stem, and to all plants having the same property, ought never to be practised with those having a different nature; for, if stems do not root as fast as they are buried, nothing but injury will follow from the sinking.

It is by paying constant attention to the shifting of the growing plant, by the employment of a very rich stimulating soil, and by a thorough knowledge of the kind of atmosphere which suits them best, that have been obtained many of those magnificent "specimen plants" which so justly excite the admiration of every body at the Metropolitan exhibitions of flowers.

In order that plants which have arrived at any considerable magnitude may suffer as little as possible from shifting, experience tells us that the operation is most advisable at the end of autumn when growth for the year is over, so that they may be ready to root with vigour when the growing season of spring returns.

It must not, however, be supposed that all the noble specimens of potted plants that decorate English gardens are obtained by repeated shifts. On the contrary, in some cases a plant is placed at once in the pot which is ultimately to contain it, and is thus enabled to grow as if in the open soil. This is called technically the "*one-shift system*," and was first brought under public notice by Mr. W. P. Ayres, the substance of whose statement was as follows:—The peculiarity of this system is, that, instead of taking a plant through all the different sized pots, from a thumb to a 24 or 16, or any other size that it may remain in permanently, it is removed to the permanent pot at once, or at any rate to one very considerably larger than is the general custom; thus, in purchasing small specimens of new plants, they may be placed at once in a 24, 16, or 12 sized pot, in which they will remain for four or five years. A cutting of Clianthus puniceus was given to Mr. Caie, gardener to the Duchess of Bedford; who at the end of twelve months had grown it into a plant 7 feet in height, beautifully branched, and covered with bloom; while the original plant under my care, although attended with regularity, would not bear a comparison with it. I learnt from Mr. C., that his cutting, directly it was established in a small cutting-pot, was removed to a No. 4 sized pot, well drained, and filled with rough turfy loam fresh from the field, and a little leaf-mould. About the same time Mr. C. offered me some small plants of Erica physodes and pinifolia, but they were in such a deplorable condition that I did not consider them worthy of carriage. To show me, however, how much I was mistaken, Mr. C. removed them from the small pots in which they were then growing into 16s, in rough turfy peat and silver sand, and in two years they were handsome specimens, 18 inches high, from four to five feet in circumference, and beautifully furnished with branches. Since

that time, I have practised this mode on various plants with success; but to Mr. Goode, gardener at Ealing Park, belongs the credit of applying this system more extensively and with greater success. Amongst the plants at that place, he has a great number in 24, 16, 12, and 8 sized pots, forming magnificent specimens, which are on an average from three to five feet in circumference, and which a year since were either in small 60 or thumb-pots. They have, in reality, made from three to four years' growth in one season, and are flowering in the greatest profusion. Among other genera, may be mentioned Boronias, Eriostemons, Leschenaultias, Pimeleas, Gnidias, Helichrysums, Ericas, Epacrises, Chorozemas, Polygalas, Roellas, Mirbelias, Dillwynias, Croweas, and Gompholobiums. The principal thing to attend to is to have the pots thoroughly drained; for if water stagnates in such a mass of soil, all hope of success will be at an end. In growing specimen plants, it is a good plan to drain the soil with an inverted pot, taking great care to prevent the soil from falling among the drainage, by covering it securely with Moss. Porous stones of various sizes, in considerable quantities, sticks in a half-decomposed state, and even charcoal for some plants, have been used, with satisfactory results. The roots of Leschenaultia formosa and of Chorozemas, thus treated, wrap round the porous stones and charcoal in the most beautiful manner. The principal things to attend to in this system of potting are, to use the soil as rough as possible. Plants potted in this way will not require so much attention as those potted in the usual manner; because one watering will serve them for several days—whereas in small pots, they require constant attention.

Innumerable criticisms of this method of cultivation were published when it was first brought into notice; but they are all forgotten, and no other valid reason can now be given for objecting to it than that it is too favourable for growth, and renders plants inconveniently large for most people's space and means. There can be no doubt that, under good management, if the gardener's object is to make a plant as vigorous as possible, it is better to avoid the troublesome details of shifting from one sized pot into another. No better evidence of this is needed than what

we see in nature. A plant in the open ground, or in the border of a well-managed conservatory, grows fast, acquires a rich deep green healthy colour, and produces its flowers and fruit as soon as it has arrived at the proper age; on the other hand, the same kind of plant, under the same circumstances, managed by the same gardener, but kept in a pot and subjected to a course of shifting, although it may be healthy at first, soon ceases growing, and becomes yellow, lean, and starved. It is not, indeed, the wish of every cultivator to grow plants for horticultural exhibitions. Beautiful as large well-grown specimens may be, it is not in every garden that they can be properly accommodated; and where that is the case, it is useless to attempt it.

Gardeners till lately entertained the opinion that in pot cultivation it is of great importance that the pot itself should be manufactured from some soft porous material. The latter was thought to have the merit of keeping roots in free communication with the air. But no well-grown plants are ever so placed as to have their roots cut off from communication with the atmosphere; the loose crocks used for drainage, and the interstices in the soil itself, enable the air to reach the roots without any assistance from the sides of the pots. Others were of opinion that the porous sides of soft-burnt pots act as a continual drain, carrying off the superfluous water of the soil. That is no doubt true; but there is as much inconvenience as advantage attending it, because, in dry weather, the earth in pots is disadvantageously dried by the escape of vapour through their sides, and cooled down by the rapid evaporation going on there. Besides, such a mode of drainage cannot be necessary if the bottom of the pots is preserved in a proper state. The absorbent power of soft-burnt garden pots, a quality due to their porosity, was also regarded as rendering them better than hard ones for cultivation. Experiment has, however, settled the question by showing that plants will grow in glass, in slate, in glazed earthenware just as well as in soft-burnt pots; and it is now admitted on all hands that if plants are ill-grown it is the fault of the gardener, not of the pot, whether it be hard or soft.

CHAPTER XVI.

OF TRANSPLANTING.

As soon as man attempted to beautify his residence with trees planted round it, he would naturally obtain them from the forest, and he then would find that, of many that he removed, all or some at least would die; if, however, he persevered he would at last discover that while constant failure attended his efforts at one time, comparative success would crown them at another; and he would thus be led to investigate, according to his skill, the causes of success and failure. Out of this would grow in time the art of transplanting, among the most important business of the gardener.

I fear, however, it is too generally practised as an empirical art, without sufficient attention being paid to the principles on which its success or failure depend; at least, one hardly knows how to draw any other conclusion from the opposite opinions held by planters, the dogmatical manner in which they are too often expressed, and the obscure and unintelligible phraseology of what are called explanations of the practice by amateurs, to whom it is not necessary to allude more particularly. If there is any one part of the art of Horticulture in which *post hoc* has been mistaken for *propter hoc* more commonly than another, it is surely in what concerns transplantation.* And yet the rationale is simple enough, if we do not labour to render it confused by imaginary refinements.

* It is scarcely necessary to say that these remarks *do not*, in any way, apply to Mr. Macnab's *Hints on the Planting and general Treatment of Hardy Evergreens in the Climate of Scotland*, an excellent treatise, which it is impossible to recommend too strongly to the attention of the planter.

When a plant is taken out of the ground for transplanting, its roots are necessarily more or less injured in the process, and consequently it is less able to support the stem than it was before the mutilation took place; its loss of this power will also be in proportion to the extent of the mutilation, which may be carried so far as to amount to destruction.

But the importance of their roots to plants is not alike at all seasons; in the summer, when there is the greatest demand upon them in consequence of the perspiration of the foliage, they are most essential; in winter, when the leaves have fallen, they are comparatively unimportant, as is evident from a very common case. Let a limb of a tree be felled in full leaf in June; its foliage will presently wither, the bark will shrivel and dry up, and the whole will speedily perish; but, if a similar limb is lopped in November, when its foliage has naturally fallen off, it will exhibit no sign of death during winter, nor till the return of spring, when it may make a dying effort to recover, but the means it takes to do so, namely the emission of leaves, only accelerates its end.

These two propositions really include all the most essential parts of the theory of transplantation, as will presently be seen; it is necessary, however, that they should be applied in some detail, for which purpose it will be convenient to consider, first the *season*, and secondly the *manner* in which transplanting can be best effected.

It is the powerful perspiratory action of the leaves of deciduous trees which renders transplanting them in a growing state so difficult, that for practical purposes it may be called impossible; for the operation is necessarily* attended by a mutilation of the roots which feed the leaves. At no period, then, can the operation be performed if such plants are growing. Even if the buds are only pushing, the process should be avoided, because immediately after that period the demand upon the roots is greatest; for although in consequence of the smallness of the surface of the young leaves the action of

* Transplanting from garden pots, in which the roots are preserved artificially from injury, may be performed equally well at any time, and is, of course, not included in this statement.

perspiration may seem to be feeble, yet the thinness of the newly formed tissue will not enable it to resist the drying action of the atmosphere unless there is a most abundant afflux of sap from the roots. In England, too, the months when buds begin to burst forth are objectionable, not only on account of their dryness, but of their coldness, which prevents the free circulation of sap; and the evil effects are felt not only by the roots through the foliage, but directly, as will be shown hereafter.

The season, then, which ought to be chosen is the period that intervenes between the fall of the leaf in autumn and the earliest part of spring, before the sap begins to move and the dry cold winds of that season to prevail. I entirely agree with Macnab, that the earliest time at which planting can be effected is, upon the whole, the best; a conclusion to which he has come from his extensive practice, in which my own observation of a great deal of planting for the last twenty-five years coincides, and which is, in all respects, conformable to theory. As soon as a plant has shed its leaves it is as much at rest for the season as it will be at any subsequent period, unless it is frozen; its torpor, indeed, is greater at that time, because its excitability is completely exhausted by the season of growth, and it has had no time to recover it. If, at that time, a root is wounded, a process of granulation or cicatrisation will commence, just as it does in cuttings; and from that granulation, which is a mere development of the cellular system, roots will eventually proceed. Now, it is obvious that since roots *must* be wounded in the process of transplantation, the sooner the wound is made the better, because it has the longer time in which to heal: and therefore the earlier in the autumn transplanting is effected, the less injury will be sustained by the plant submitted to the process; in the technical language of the gardener, "it has the more time to establish itself." Deciduous trees usually begin to assume their autumnal hue in September, and as soon as that has happened they may be transplanted with safety.

Autumn and early winter are, moreover, the best seasons, because of their great dampness. It will be seen by reference

to Mr. Thompson's tables (page 954), that the air is very generally in a state of saturation in the months of October, November, December, January, and February, and that it is seldom in that condition at any other season. Now, although the perspiration of plants is greatly diminished by the removal of the leaves, it is not destroyed, for they also absorb and perspire through their young bark; and therefore a saturated atmosphere, which prevents much of the perspiratory action which remains from being exercised, is a condition, even when plants are leafless, much too beneficial to be overlooked. Nor is the action upon the perspiratory power of the stem the only mode in which a saturated atmosphere is important at the time of transplantation; it exercises a directly favourable influence on the formation of roots themselves.

> It is sometimes necessary to assist a tree, when it begins to grow, by syringing it with a water-engine, or by binding the main branches and stem with moss. The object of this is partly to stop evaporation through the bark, and partly to encourage absorption by the bark.

It is doubted, indeed, whether in the cold months of the year trees make roots. Some physiologists peremptorily deny the possibility of roots appearing in the absence of leaves, and therefore, although they do not altogether object to the assertion that roots are formed in winter or late autumn, they only admit that possibility in the case of evergreens. Their theory is that roots are formed by the action of leaves; and that therefore when leaves are off roots will not grow. Their theory is wrong; they should use their eyes. In 1845 I examined, on the 26th February, the roots of various trees, and found young ones formed abundantly on Sambucus racemosa, Ribes sanguineum and divaricatum, the Sycamore, Plum, Peach and Apple. Such evergreens as Hollies, Garrya, Common Broom, and Portugal Laurel, had also produced them in large quantity. The statement, therefore, that roots can only be formed in the presence of leaves is erroneous.

Roots at their spongioles, or most absorbent points, are extremely delicate parts, unprotected by a fully organized epidermis, destined to exist in a moist medium, and capable of being easily killed by exposure to dryness as well as by actual

violence. The accidents to which the roots of transplanted trees are liable, from the very nature of the operation, are of such a kind that it is impossible to prevent their being exposed to the air, sometimes for considerable periods of time; it is therefore obviously a point of the first importance, that the air should be as nearly of the humidity of the soil from which the roots have been extracted as can be secured. How unfavourable, in this point of view, the months of March, April, and May are for planting, is apparent from Mr. Thompson's tables above referred to; how little the matter is attended to by nurserymen, gardeners, and labourers, all great planters know to their cost. Macnab, who thoroughly understood all this, preferred a moist rainy day; although, as he says, he has "at times been as wet in planting evergreens, as when exposed for hours on the windy side of Ben Nevis in a wet day, without great coat and with a broken umbrella." It may be very true that good plantations have been made in March and April; it may be equally true that no such care as I have described is necessary for all plants; but no wise man would, on that account, neglect the precautions which the nature of plants shows to be necessary to insure success with all things. Very wet and warm springs may prevent the loss of any considerable proportion of the trees planted in March and April, especially if succeeded by a dull, warm, wet summer; and a Willow may be planted with success at midsummer: but we cannot tell beforehand what sort of spring is coming, and all plants have not the tenacity of life possessed by a Willow.

If the months from September to December are the most favourable for transplanting deciduous trees, and March and April the worst, how much more important must be those periods to evergreens. An evergreen differs from a deciduous plant in this material circumstance, that it has no season of rest; its leaves remain alive and active during the winter, and consequently it is in a state of perpetual growth. I do not mean that it is always lengthening itself in the form of new branches, for this happens periodically only in evergreens, and is usually confined to the spring; but that its circulation, perspiration, assimilation, and production of roots are incessant.

Such being the case, an evergreen, when transplanted, is liable to the same risks as deciduous plants in full leaf, with one essential difference. The leaves of evergreens are provided with a thick hard skin, which is tender and readily permeable to aqueous exhalations only when quite young, and which becomes very firm and tough by the arrival of winter, whence the rigidity always observable in the foliage of evergreen trees and shrubs. Such a coating as this is capable, in a much less degree than one of a thinner texture, such as we find upon deciduous plants, of parting with aqueous vapour; and, moreover, its stomates are few, small, comparatively inactive, and chiefly confined to the under side, where they are less exposed to dryness than if they were on the upper side also. But although evergreens from their structure are not liable to be affected by the same external circumstances as deciduous plants in the same degree, and although, therefore, transplanting an evergreen in leaf is not the same thing as transplanting a deciduous tree in the same condition, yet it must be obvious that the great extent of perspiring surface upon the one, however low its action, constitutes much difficulty, superadded to whatever difficulty there may be in the other case. Hence we are irresistibly driven to the conclusion that whatever care is required in the selection of a suitable season, damp, and not too cold, for a deciduous tree, is still more essential for an evergreen. It is, therefore, most extraordinary that it should have ever been the practice to defer the planting evergreens till late in the spring upon the supposition that it is the very best season for them, as if cold winds, accompanied by from 20° to 30° of dryness in the air, which is not more than ·500 or ·357 of moisture, with a bright sun beating on the roots which are exposed, and exciting the action of the perspiring surface to the utmost extent of its power, were external conditions with which the gardener has no concern; and yet, as Macnab justly observes, half a day's sun in spring and autumn will do more harm immediately after planting than a whole week's sun from morning to night in the middle of winter.

The Holly, says a writer in the *Horticultural Transactions*, does not succeed well, if transplanted at any other season of the

year than the end of April or beginning of May; at this time the buds are just breaking open into leaf, and I have rarely failed of success in transplanting small, or even very large old, trees. (ii. 357.) Although such statements cannot be too strongly contradicted as guides to practice, yet it is not difficult to explain their origin. Since evergreens are never deprived of their leaves, so they are never incapable of forming roots; on the contrary, they produce them abundantly all winter long, and rapidly at any other period of the year which is favourable to their growth; so that they are capable of making good an injury to their roots much more speedily than deciduous plants: especially as in the majority of cases the roots are numerous and fibrous, and not so liable to extensive mutilation when transplanted. Now, if an evergreen is planted in the month of May and the weather *happens* to be cloudy, warm, and damp, as the plant is just then commencing the renewal of its growth, and is forming fresh roots abundantly, if such a state of weather lasts for a week or two, there is no doubt that the plant will succeed very well.

"I differ with the doctors about planting evergreens in spring; if it happens to be wet weather, it may be better than exposing them to a first winter; but the cold dry winds that generally prevail in spring are ten times more pernicious. In my own opinion the end of September is the best season, for then they shoot before the hard weather comes." —*Horace Walpole*, page 176, vol. 3.

It is said that if a tree is just budding when planted it is in the most favourable state, because it will immediately make fresh roots, the act of vegetation upwards being simultaneous with growth in a downward direction; and that is true. There is here, however, a fallacy; it is assumed that the upward and downward vegetation will go on when a plant is transplanted as well as if it is left in its former place; that, however, depends upon the external conditions to which it is exposed. If the surrounding air is damp, and remains so, evaporation being thus prevented for a sufficiently long time, roots will be quickly formed, and the plant will go on growing; on the other hand, if the air is dry and exhausts the branches of their moisture, new roots cannot be formed, and the plant will die. Life, in such a case, is staked upon the chance of the atmosphere being in a very favourable state, and the chances are ten to one against its being so. The cause of death when trees are removed is almost entirely, as already stated, that they lose the fluid contained within them faster than it can be renewed, the end being the

drying up of their vessels, which is immediately followed by a loss of vital force. If we inquire whether the circumstances to which spring-planted trees are exposed are favourable or unfavourable to this fatal loss of fluid, we find them to be the former in an enormous degree. The air is peculiarly dry in the spring, and frequently in rapid motion at the same time; all objects exposed to a current of dry air must part with their moisture rapidly, and consequently such a state of things is most unfavourable to plants which require to retain their moisture. At first their young bark is the channel through which the moisture flies off, but as soon as young leaves appear, should the trees live long enough, and the perspiring surface is thus extended, this loss goes on with far greater rapidity, and life is soon extinguished. Evergreens, which have always a very large perspiring surface, are on that account exposed to much more danger, and consequently the losses among them are much greater. That the excessive loss of fluid from the interior is the true cause of death in newly-planted trees was proved by, we think, Mr. Knight, who surrounded their stems with damp moss and thus preserved them.

In the year 1822, in the month of August, there were planted in the garden of the Horticultural Society of London above six thousand Hollies, from two to three feet high, for the purpose of forming fences; few plants in all that number ever exhibited any traces of having been removed, and I do not believe that a hundred died. The weather was dry, but the plants were deluged with water when placed in their holes, and they had been obtained from the Regent's Park, where they grew in the stiff clay of that side of London, the consequence of which was that, when taken out of the ground, so much earth adhered to them that they were almost in the state of plants removed from pots. Transplanting evergreens even at mid-summer has many able advocates, and there is no questioning the fact that this season has been found eminently propitious. But at midsummer the air and soil are in a very different state from any part of the spring. Both are warm and moist, and furnish the operator with highly favourable conditions.

The proper time at which to transplant evergreens has now been finally and conclusively determined, so far as the south of England is concerned. Mr. Glendinning, a nurseryman of great experience, agreeing in opinion with Horace Walpole, has recorded it as the result of his practice that August is a good month to begin in, September being the safest month. Many

experiments have been made year after year to test the soundness of that conclusion, and they have uniformly confirmed it.

In September, 1849, the following work was done within my own observation. 1. Some hundred feet of a Holly hedge, about twenty-five years old, were transplanted, and although from the dryness of the soil, badness of roots, and other causes, there was great reason to fear the result, these plants were in June, 1850, with a very small number of exceptions, safe and growing. 2. A Holly-tree about twelve feet high, forming part of the same hedge, which had been left for some days with its roots covered by a mat, and was much dried, was carried a quarter of a mile and replanted. It cast its old leaves, and pushed well. 3. The following plants were also transplanted at the same time. Several common Laurels and Portugal Laurels, from four to six feet high, dug out of a shrubbery; seventy-five Rhododendrons, fourteen Arbor-Vitæ, four to five feet high; sixteen Laurustinus; nine Yews, four to five feet high; four green Hollies of the same size, two Cupressus torulosa, and some other plants. They were all taken from the open quarters of a nursery, not having been potted; the weather was hot and dry. The only casualty among them consisted in one Arbor-Vitæ having died. The Cypresses were half killed by the winter; and a few of the Yews made buds slowly, but lived.

Mr. Glendinning urges the great importance of considering the temperature of the soil in the autumnal months, and prefers the earliest available period *because of the higher temperature of the soil at an early than at a late period.* He very justly says that early in the autumn the roots of transplanted evergreens find themselves in a "gentle bottom-heat." Mr. Thompson's invaluable tables of ground temperature near London show what is the real gain in this respect. He found the mean temperature of the soil, on an average of six years, to be—

	One foot deep.	Two feet deep.
August	62·37	61·95
September	58·35	59·04
October	52·38	53·74
November	46·79	48·09
December	40·75	42·89

Thus, in August, the earth is from 8° to 10° warmer than in October, and in September about 6° higher than in October, 10° to 12° higher than in November, and 16° or 17° higher than in December.

Here we have a great element of advantage in favour of August; for although evergreens will make new roots all the year round, if the earth is not too cold, yet it is certain that they will do so much more quickly and abundantly in warmth than in cold; and 10° form what may be called, without exaggeration, an immense difference in their favour. But, on the other hand, they will be seriously obstructed in the operation of forming new roots, even in "bottom-heat," if their leaves are shrivelled up and destroyed: as is always to be dreaded at too early a period of the year. If we examine the facts from which we are to judge of the dryness of our autumnal months we find them to be as follows:—

Mean degree of dryness according to Daniell's hygrometer, on an average of nineteen years.

August	4·45
September	2·11
October	1·62
November	0·93
December	0·72

Dryness of the above period according to the hygrometric scale, saturation being represented by 1000.

August	851·
September	903·
October	947·
November	963·
December	969·

Mean temperature, average twenty-three years.

August	62°·17
September	56°·72
October	50°·46
November	43°.00
December	39°·76

These facts show that August is fully twice as dry as September, and nearly four times as dry as October; also that the mean

temperature of August is more than 6° higher than that of September, and of September than of October. Now as the loss of water by trees is to a great degree dependent upon the dryness of the air, it is obvious that in that point of view August is almost four times as dangerous as October.

It must also be borne in mind that perspiration in plants is caused by the direct action of light, and that loss by perspiration is in proportion to the length of time during which the surface of plants is exposed to sunlight; heat and dryness only increasing the amount. Now, in August the days are not only longer but brighter than in September, and in September than in October; and here, again, the state of the atmosphere is against the first month and in favour of the latter.

If from these data alone we had to decide theoretically which of the autumn months is the best, the choice would fall on September; and this coincides with experience. August has the advantage in the temperature of the soil, but is too dry and light. In September dryness and light have become more moderate; the temperature of the soil has not fallen more than 4°, and evergreens then planted have two clear months in which to form new roots. October has the advantage in a lower temperature and more diminished light; but the soil is 6° colder than in September and it leaves the worst of two months for new roots to develope in. For such reasons it would seem that September is better than either August or October, October than August or November, and August better than November.

Macnab rightly adverts to the importance of choosing a suitable day, as well as season, for the operation; and it must be evident from what has now been stated, that this is very necessary: "In winter, you may plant with perfect safety in a dull calm day, whereas in spring or autumn a moist rainy day is preferable to any other; but where a person has not the choice of such weather, then the work should be performed in the evening, when the sun gets low, especially in spring or autumn planting."

Next in importance to the selection of a fitting season, is the preservation of the roots of transplanted trees; the former is

of little consequence, if the latter is not attended to. We know, indeed, that some plants will live with the rudest treatment, and bear the most severe mutilation without much suffering; but those are special instances of extreme tenacity of life, and do not affect general principles. The value of great attention to the roots, in the operation of shifting, has already been pointed out (p. 448), and transplanting is only shifting under another name. It would be the duty of the gardener to save every minute fibre of the roots, if it were practicable; but, as that is not the case, his care must be confined to lifting his trees with the least possible destruction of those important organs; remembering always that it is not by the coarse old woody roots that the absorption of food is most energetically carried on, but by the youngest parts, and especially the spongioles. The mechanical means by which this is best effected do not belong to the present subject; I may however remark, without quitting the limits of theory, that, as the greater part of the young fibres is produced at the circumference of the circle formed by the root, the earth should be first removed at some distance from the stem, so as to insure, as far as possible, their being taken up entire; if this is not done, but the spade is struck into the earth near the stem, or if the rude nursery practice, justly enough called drawing, is employed, a large part of the most valuable roots must necessarily be cut off or destroyed by tearing.* The greatest difficulty, beyond that of mechanical removal, in transplanting trees of considerable size, is this preservation of roots; and, if it were possible to carry without injury such heavy masses as old forest trees, there would be no physical obstacle to transplanting them, if the extrication of the fibrous part of the roots could be secured. As, however, the latter is a troublesome and very difficult operation, even when trees are only ten or twelve feet high, it has been, from time out of mind, the custom of skilful planters to prepare such trees for removal by

* The violent manner of transplanting trees by McGlashan's machinery, in which large roots are torn up with much laceration, is, however, very favourably reported on. But so far as very large trees are concerned it stills stands at the bar of public opinion, and will have to be judged hereafter.

cutting back their main roots one year before they are to be transplanted; if this very simple operation is properly performed, all the principal limbs, so amputated, will emit young fibres in abundance from their extremities, and the gardener, from knowing where to find those roots, can easily take them up without material injury.

A better method is to describe in August a circle round a tree at three or four feet from its trunk; outside that circle to cut a very narrow trench, with a draining spade, or some similar instrument, two to three feet deep; and to fill in the trench with leaf-mould or some rich loose material, among which fibres will readily form. If this is done at the time when trees are making their second growth so large a quantity of fibrous roots will have been formed by October as to render it possible to transplant trees thus prepared without risk of losing them.

In order to effect the same end, but in another way, the following expedient has been occasionally employed for large trees. A deep trench has been opened, in mid-winter, round a stem, at such a distance as to be clear of the principal fibres; the tree has then been carefully undermined, till, at last, the earth belonging to it has formed a huge ball; upon the approach of frost, water has been freely poured over the ball so that its whole surface may be converted into an icy mass; in that state it has been raised by powerful tackle, and conveyed without disturbance to its intended site. This operation is unobjectionable for hardy trees of great size, but is expensive, and only capable of application in a limited degree; its success is entirely owing to the young and tender fibres being placed in such a position that they cannot be injured by the act of transport.

Although it is a principle with vegetable physiologists that a tree of any age, or dimensions, may be safely transplanted, provided its roots can be preserved, and mechanical means be found for lifting a mass so ponderous as a forest-tree with the earth in which its roots are embedded, yet the difficulties attendant upon carrying out the principle are such as to deter most persons from trying the experiment. That there really is no difficulty in the matter, except such as skill and adequate means can wholly overcome, is sufficiently proved by the extent to which the transplantation of large trees has been carried at Elvaston Castle. But people evidently think that Lord Harrington's success is an exceptional case;

they do not put entire confidence in Sir Henry Steuart's results, and they feel alarmed at what that writer says of the issue of a great experiment tried at Edinburgh some years since, when the site of the Botanic Garden was changed. In the first place, as to the expense of the experiment, this writer says it would be needless, as well as invidious, to investigate that, as it could be no object in a royal institution; and, secondly, he speaks rather coldly of the result, when he merely says that "the removals were executed with a safety which could scarcely have been anticipated." The meaning which this was intended to convey is now explained in the notes to the third edition of the *Planter's Guide*, page 386, where we are distinctly informed that although some things had succeeded well, yet that "the ordinary forest-trees on the other hand, such as the Lime, the Birch, and the Walnut, appeared by no means so successful, although powerfully supported with cordage." Faint praise like this was not calculated to hold out great expectations of success in transplanting large trees, considering that Macnab was the operator; and it must have greatly contributed to damp the ardour of those who would have been otherwise encouraged by the success said by Sir Henry to have attended his own proceedings.

The practicability of removing large trees by ordinary means has, however, been finally set at rest, *in a manner open to no question*, by a large experiment in transplanting trees from ten to forty-nine feet in height, at Amport House, near Andover, the seat of the Marquess of Winchester. Mr. Joseph Holmes, the gardener there, has published an account of the operation in a paper in the *Journal of the Horticultural Society* (vol. vi. p. 14). In this communication he describes with minuteness the method he pursued, the difficulties that occurred, and the final result of transplanting about a couple of hundred trees of large size from a sheltered valley to much higher ground. The trees consisted of

Yews	7 . . .	from 10 to 24 feet in height.
Oaks	18 . . .	,, 16 ,, 27 ,, ,,
Beech	60 . . .	,, 16 ,, 49 ,, ,,
Birch	3 . . .	,, 19 ,, 42 ,, ,,
Elms	22 . . .	,, 16 ,, 36 ,, ,,
Limes	5 . . .	,, 13 ,, 36 ,, ,,
Hornbeam . . .	36 . . .	,, 30 (on an average)
Horse-chestnuts .	25 . . .	,, 14 ,, 33 ,, ,,
Sycamores . . .	28 . . .	,, 15 ,, 37 ,, ,,

In all 204 such trees were planted, of which 199 remain. The only one which failed is thus spoken of by Mr. Holmes. "In transplanting upwards of 200 trees, not one of the number failed, and it was found necessary to sacrifice only one tree. The instance I allude to was that of a fine Beech, forty-two feet high, removed on Sir H. Steuart's

principle. The tree was rooted equally well with any of its contemporaries, but it had no ball; hence it was difficult to rear upright, and notwithstanding every care in propping, the first high wind laid it prostrate, when it was not considered worthy of further trouble."

His mode of proceeding, after the trees were deposited in the places intended for them, is described thus:—"In placing the tree on its new site, nothing more is necessary than to have a good hole made a foot or more wider every way than the roots extend. A roadway for the truck is cut from the natural surface to the bottom of the hole, and on the opposite side means are afforded for the horses to get out of the hole. The truck being in the middle of the latter, loosen the chain, take out the pole, bring down the head of the tree, so as to allow the edge of the ball to touch the bottom of the hole, then draw out the truck; and should the tree not have got quite an upright position, pull the ropes to render it so, at the same time packing the ball with fine soil, until it stands upright of itself. Every root that has been injured in taking up, should now be cut smooth, and every one laid out as straight and natural as possible, resembling the rays of a circle, great care being taken to pack fine soil firmly round the ball, and to surround every fibre with the best and finest soil, until every root is covered. Immediately after transplanting, every tree was *mulched* with old thatch, as far as the roots extended; and they also had a covering of about half an inch of straw around their stems, from eight to twelve feet from the ground. This was done principally with the view of lessening the demand made upon the tree by evaporation. The straw was found to keep damp a considerable time after every rain. A ridge of soil was also placed around each tree, at the extremity of the roots, forming a sort of cup; and I have frequently seen water standing in these cups half an hour after heavy rain, during the second summer after planting, as by this time, from various causes, the mulch had disappeared, and the surface was firm, owing to the constant treading of sheep, which were allowed to feed among the trees during the second summer after planting, and which was, no doubt, favourable to them. No further care was bestowed or considered necessary; and no tree was ever watered, except during the first three weeks after transplanting, when the water-cart was used to most of the two groups of Hornbeam at the time they were in green leaf; and it was thought that thereby an early root action would be induced."

The precise fate of each tree is described in a set of tables, from which we gather two or three striking facts. A Beech-tree, forty-two feet high, made wood twelve inches long the first year, and seven inches in the two succeeding years; another, forty-eight feet high, made eight inches in the first year, and eight and six inches afterwards; another, forty-nine feet high, which did not make more than four inches of shoot the first year, made six the second, and eight the third

year (1850). The annual extensions in the three years after removal were thus in the following instances:—

Elm	21 feet high	4 —12—13 inches.	
,, ...	36 ,,	3 — 2— 6 ,,	
,, ...	29 ,,	3 — 5— 6 ,,	
Birch	42 ,,	4 — 4— 6 ,,	
Oak	25 ,,	5 — 3— 5 ,,	
,, ...	25 ,,	4 — 4— 4 ,,	
,, ...	26 ,,	5 — 2— 3 ,,	
Hornbeam . .	30 ,,	3½— 6— 7 ,,	on chalk.
,, ...	30 ,,	3½— 4— 4 ,,	in loam.
Sycamore . .	36 ,,	7 — 6— 6 ,,	
,, ...	34 ,,	3 — 2— 2 ,,	
,, ...	37 ,,	2 — 2— 3 ,,	

What was very important, with reference to the final issue of this experiment, was the state of the roots, after three years' removal, and an excessively dry autumn. I can state that their condition was in every respect satisfactory. I myself saw fine fibrous roots, three feet long, taken from the Sycamore No. 16, thirty-seven feet high, when transplanted, whose shoots lengthened two inches the first year, two inches the second, and three inches the third. This tree was transplanted December 29th, 1847; it was taken from a very low, damp, dense shrubbery, surrounded by tall trees, and was transplanted to the most high and exposed part of the new park; apparently for fourteen years the tree had had two leaders; one of these rival leaders was cut off in March, 1849. This tree was also affected by the wind more than any other, by reason of its heavy head, as compared with the stem. It was, therefore, a good one to be subjected to a root examination, as no tree had to contend with such a number of unfavourable circumstances, or appeared to be doing worse. The roots, however, were found, on examination, to be an entire mass, similar to what I have described, in a hole of eleven feet diameter.

Under ordinary circumstances, the roots must necessarily be injured more or less by removal; in that case, all the larger wounds should be cut to a clean smooth face; not in long ragged slivers, which is only substituting one kind of mutilation for another, but at an angle of about 45°, or less. If the ends of small roots are bruised, they generally die back a little way, and then emit fresh spongioles; but the larger roots, when bruised, lose the vitality of their broken extremity, their ragged tissue remains open to the uncontrolled introduction of water, decays in consequence of being in contact with an excess of

this fluid, and often becomes the seat of disease which spreads to parts that would otherwise be healthy. To this it may be added that decaying roots become the seat of dry-rot fungi, which, once established, rapidly introduce their spawn among the living tissues, and produce diseases which only end in death.

When, however, the wound is made clean by a skilful pruner the vessels contract, and prevent the introduction of an excess of water into the interior; the wound heals by granulations formed by the living tissue, and the readiness with which this takes place is in proportion to the smallness of the wound. It may be sometimes advantageous to remove large parts of the coarser roots of a tree, even if they are not accidentally wounded when taken up, the object being to compel the plant to throw out, in room of those comparatively inactive subterranean limbs, a supply of young active fibres. This is a common practice in the nurseries when transplanting young Oaks and other tap-rooted trees, and is one of the means employed by the Lancashire growers of Gooseberries, in order to increase the vigour of their bushes; in the last case, however, the operation is not confined to the time when transplantation takes place, but is practised annually upon digging the Gooseberry borders. The reason why cutting off portions of the principal roots causes a production of fibres appears to be this: the roots are produced by organizable matter sent downwards from the stem; that matter, if uninterrupted, will flow along the main branches of the root, until it reaches the extremities, adding largely to the wood and horizontal growth of the root, but increasing, in a very slight degree, the absorbent powers; but if a large limb of the roots is amputated, the powers of the stem remaining the same, all that descending organizable matter which would have been expended in adding to the thickness of the amputated part is arrested at the line of amputation; and, unable to pass further on, rapidly produces granulations to heal the wound, immediately after which young spongioles appear, soon establish themselves in the surrounding soil, and become the points of new and active fibres.

By many excellent planters, the advantage of deluging the

roots with water, when newly planted, is much insisted on; and in the case of large plants, particularly evergreens, it is, undoubtedly, an essential process, partly because it causes the flagging and injured roots to be immediately surrounded by an abundant supply of liquid food, which, if the operation be skilfully performed (see Macnab's *Treatise*, pp. 24 and 25), will not subsequently fail them; and partly because it is the only means we possess of embedding with certainty all the fibres in soil. When the earth is reduced to the state of puddle, it will settle round the finest roots, and place them as nearly as possible in the same condition, with regard to the soil, that they were in before the plants were removed. But the operation of puddling is unnecessary to small plants, if removed at a proper season of the year, especially to deciduous trees of all kinds; and it may be injurious. This was long ago stated by Mr. Knight (*Hort. Trans.* iii. 159), who found by experience that when trees are very much out of health, in consequence of having become dry, excess of moisture to the roots is often fatal. This appears to arise from the languid powers of the plant being insufficient to enable it to decompose and assimilate the water rapidly introduced into its system through wounds in its root, or by the hygrometrical force of that part; under such circumstances, water will dissolve the mucilaginous and other matters intended for the support of the nascent buds, which matters then putrefy, lose their nutritive quality, and destroy the tissue. The substitute for root-watering contrived by Mr. Knight in such cases was, to keep the plants in a situation shaded from the morning sun, and to moisten their bark frequently; by these means water is presented to them slowly through the young cortical integument, which, partaking of the nature of a leaf, slowly absorbs it, probably decomposes it, and transmits it laterally through the liber into the alburnum, where it finds itself in the ordinary channel of the ascending sap, and thus enters the system of circulation. In this way Mr. Knight succeeded in preserving American Apple-trees, which reached him in the middle of April, in so bad a state that they seemed "perfectly lifeless and dry," and "much better fitted for fire-wood than for planting."

CHAPTER XVII.

OF THE PRESERVATION OF RACES BY SEED.

THE manner of preserving the domesticated races of plants by the ordinary means of propagation, such as cuttings, layers, grafts, and so on, has already been explained; there are, however, other topics connected with this important subject which require to be touched upon.

Propagation by division is inapplicable to annuals or biennials, or at least can be practised upon only a very limited scale, and for such plants the gardener has to trust to seeds alone. But it is an axiom in vegetable physiology that seeds reproduce the species only, while buds (that is, propagation by division) will multiply the variety; and this is undoubtedly true as a general rule. But the skill and care of the gardener often enable him to perpetuate by seed the many races of cultivated annuals, varieties of the same species, improved and altered by centuries of domestication, with as much certainty as if he were operating with cuttings. In a well managed farm we see the various breeds of Turnips and Corn preserving each its own peculiar character unchanged year after year, and yet they must all be propagated by seed alone; and in gardens the varieties are innumerable of Peas, Lettuces, Cabbages, Radishes, &c., whose purity is maintained by the same means. The manner in which this is effected is of the first importance to be understood.

Although it is the general nature of a seed to perpetuate the species only to which it belongs, and it cannot therefore be relied upon, in ordinary cases, to renew a particular variety of

the species, yet there is always a visible tendency in it to produce a seedling more like its parent than any other form of the species. Suppose, for example, the seed of a Ribston Pippin Apple were sown; if untainted by intermixture with other varieties, it would produce an Apple-tree whose fruit would be large, sweet, and agreeable to eat, and not small, sour, and uneatable like the Wilding Apple or Crab. The object of the gardener is to fix this tendency, and he does it by means not unlike those employed in the preservation of the races of domesticated animals, namely, by "breeding in and in," as the phrase is. An example of this will be more instructive than a dissertation. The Radish has, when wild, a long pallid root; among many seedlings one was remarked with roots shorter and rounder, and more succulent than the remainder; this was a "sport," to which all plants are subject. Had that Radish been left among its companions, and the seed saved from them all indifferently, the tendency would have disappeared for that time; but its companions were all eradicated, and the better one produced its seed in solitude. The crop of young plants obtained from this Radish was, for the most part, composed of individuals of the wild form, but several preserved the same qualities as the parent, and some, perhaps one only, in a higher degree: in this one, then, the tendency was beginning to fix. Again were all eradicated, except the last-mentioned individual, whose seeds were carefully preserved for the succeeding crop; and, by a constant repetition of this practice for many years, at last the habit to produce a round and succulent root became so fixed, that all the Radishes assumed the same appearance and quality, and there were none left to draft or "rogue." Every variety of annual crop, not still in its wild state, must have gone through this process of fixing; and thus the varieties of earliness, lateness, and productiveness, colour, form, and flavour observable in garden plants, have been secured for our enjoyment.

The following experiment has been recorded by an intelligent observer writing under the name of Lusor:—"If we breed live stock, of whatever kind, we invariably select the parents from the best of our flock or stud. So, with regard to flowers, no one would sow seed from

inferior flowers, but would select from the best specimens; and it is by following up this system (even without more crossing than is performed by Nature, and the bees), that great improvements have been made. Thinking the same effects would accrue from a more careful selection of culinary seeds, and that a much greater degree of productiveness might be attained, about three years ago I began an experiment with long-pod Beans; I carefully selected the finest and fullest pods for seed, taking none with fewer than five Beans in each. Next year I had a good sprinkling of pods with six seeds in each; these were saved for seed. The following year there were many six-seeded pods and some with seven. Following up the same plan, I find this season many more six and seven-seeded pods, than of a less number, and some with eight seeds; there are still a few plants which produce five-seeded pods, and it is worthy of remark, that the five-seeded plants have seldom a six-seeded pod upon them, but all fives; on the contrary, a six-seeded plant generally has nearly all the pods bearing six Beans or more."

By a similar process M. Vilmorin obtained domesticated Carrots from wild ones in a few generations (*Hort. Trans.*, 2nd ser., vol. ii., p. 348), and the curious experiments of M. Esprit Fabre upon fixing the character of Wheat in plants derived from an Ægilops, were conducted upon the same principles (*Journ. Agr. Soc.*, vol. xv., p. 167). In fact it is thus, and thus only, that in annual plants any improvement in quality can be rendered permanent.

There is a class of facts apparently opposed to these views. It is said that the fruit of Apple and Pear-trees, raised from the seeds of varieties of the highest excellence, will often be little better than that of wildings. This obscure subject will be considered in the next chapter, in connection with hybridity.

But to fix a new habit in annual plants is not the only care of the cultivator, whose patience and skill would be ill employed if it could not be preserved. If a plant has some tendency to vary from its original condition, it has much more to revert to its wild state; and there can be no doubt that, if the arts of cultivation were abandoned for only a very few years, all the annual varieties of our gardens would disappear, and be replaced by a few original wild forms.

For the means of preserving the races of plants pure, the means vary according to the nature of the variety. As far as concerns early and late varieties, it often happens that, as in Peas, the tendency in such plants to advance or retard their season of ripening was originally connected with the soil or climate in which they grew. A plant which for years is

cultivated in a warm dry soil, where it ripens in forty days, will acquire habits of great excitability; and, when sown in another soil, will, for a season or so, retain its habit of rapid maturity: and the reverse will happen to an annual from a cold wet soil. But, as the latter will gradually become excitable and precocious, if sown for a succession of seasons in a dry warm soil, so will the former lose those habits, and become late and less excitable. Hence, the best seedsmen always take care that their early varieties of annuals are procured from warmer and drier lands than those on which they are to be sown; our earliest Peas, for example, are obtained from France, and the next in time of ripening from the hot dry fields of Kent, the Suffolk coast, and similar situations. Thus, also, the Barley grown on sandy soils, in the warmest parts of England, is always found by the Scotch farmer, when introduced into his country, to ripen on his cold hills earlier than his crops of the same kind do, when he uses the seeds of plants which have passed through several successive generations in his colder climate; and Knight found that the crops of Wheat on some very high and cold ground, which he cultivated, ripened much earlier when he obtained his seed-corn from a very warm district and gravelly soil, which lies a few miles distant, than when he employed the seed of his vicinity. It would seem as if this were in some way connected with the mere size of a seed, the smallest seeds of a given variety producing plants capable of fructifying quicker than those of a much larger size. We have, at present, but little information upon this subject; but there are some most curious experiments relative to it by Edwards and Colin, who found that, although Winter Wheat cannot, in France, be made to shoot into ear, if sown in the spring, provided the largest grains of the variety are employed, yet that, if the smallest grains are picked out, some will ear like Spring Wheat (see *Annales des Sciences Naturales*, v. 1). Out of 530 grains of Winter Wheat, sown on the 23rd of April, and weighing 7 ounces 52 grains, not one pushed into ear, they tillered abundantly, but the tillers were excessively stunted, and concealed among the tufts of leaves; in short, they formed nothing but turf: on the other hand, of 530 other grains,

weighing 3 ounces 56 grains, and sown on the same day, 60 pushed into ear.

Some facts tend to show that many of our most esteemed garden plants are the result of debility, and that the succulence, the sweetness, or the excessive size, which render them so well suited for food, are only marks of unhealthiness. At least, it is almost necessary to assume this to be the case, in order to account for the efficacy of one of the modes of maintaining races genuine. It is perfectly well known, that, if such an annual as a Turnip is transplanted shortly before it runs to seed, the characters of its variety will remain more strongly marked, and have far less tendency to vary, than if, all other circumstances remaining the same, the seed is saved without the process of transplantation having been observed. Now, the only effect of transplanting, at the season immediately preceding the formation of a flower-stalk, would seem to be that of checking the luxuriance of the individual operated on; or, upon the above assumption, of increasing its debility of constitution. And the same explanation appears applicable to a strange custom mentioned by Mr. Ingledew as being practised in the Dekkan, to prevent the rapid deterioration, in that climate, of the Carrot, the Radish, and the Parsnep, the favourite table vegetables of the inhabitants. He states that the Indian gardeners, in the first place, prepare a compost of buffalo's dung, swine's dung, and red maiden earth, mixed with water till they have the consistence of paste, and scented with a small quantity of asafœtida, the use of which seems to be imaginary. "The vegetables for this operation are drawn, when wanted, from the beds, when they have attained about one-third of their natural growth, and those plants are chosen which are the most succulent and luxuriant; the tops are removed, leaving a few inches from their origin in the crown upwards; and a little of the inferior extremity, or tap-root, is cut straight off likewise, allowing nearly the whole of the edible part to remain, from the bottom of which to within about an inch of the crown, are made two incisions across each other entirely through the body of the vegetable, dividing it into quarters nearly to the upper end. They are then dipped into the

compost until they are well covered by it, both externally and internally, and are immediately placed in beds, previously preparêd for their reception, at the distance of fifteen or sixteen inches from each other, and so deep in the ground that the upper extremities only appear in sight. They are afterwards regularly watered; and when they take root, and fresh tops have made some advance in growth, they require but little attention. The tops speedily become large, and grow into strong and luxuriant stalks, the blossoms acquire a size larger than ordinary, and the seed they produce is likewise large and vigorous, and superabundant in quantity. Innumerable roots are thrown out from the incised edges of these plants; they consequently receive a greater abundance of nourishment, which occasions their luxuriant growth, causes them to yield not only a more than ordinary crop of seed, but also of a superior quality." (*Hort. Trans.*, v. 517.) The operation is performed at the beginning of the dry season.

Besides "roguing out" (i. e. eradicating) all individuals having the slightest appearance of degeneracy from among the plants intended for seed, care must be taken that the crop is so far from any other of a similar kind as to incur no risk of being spoiled by the intermixture of its pollen. This substance is conveyed to considerable distances by wind and insects; and it is scarcely possible to be secure from its influence, if similar crops are cultivated within some miles of each other; whence we find certain villages, in different parts of Europe, celebrated for the purity of the seed of particular varieties; this usually happens in consequence of the villagers cultivating that variety and no other, as happens at Castelnaudary with Beet, at Altringham with the Carrot, and in Norfolk with different kinds of Turnip.

It is, however, to be observed, that the deterioratiou of seed by bastardising happens to a greater extent to single plants than to large masses of them; and it seldom happens that good seed can be saved in a garden, or near gardens, from a single individual. Solitary specimens of the Turnip, the Cauliflower, and such plants, have been frequently selected on account of their perfect characters, and been carefully planted

in gardens for a stock of seed, but their produce has as frequently been of the worst description, bearing no resemblance to the parent. In such cases as these, it would seem as if bees and other insects were attracted from all quarters by the gay colours, or odour, of such isolated individuals, and, arriving from a hundred flowers which they had previously visited, bring with them so many sources of contamination.

When, however, the action of other flowers can be prevented, as in the Melon and other unisexual plants, by "setting," the largest, healthiest, and most cultivated varieties will yield seed of the purest and finest quality. The tendency of Persian Melons to degenerate in this country was remarked soon after their introduction: and for a long time it was thought impossible to preserve them for many generations. Knight, in his numberless experiments upon this fruit, found that to be the case, for his fruit at one time became less in bulk and weight, and deteriorated in taste and flavour. But when he came to consider that "every large and excellent variety of the Melon must necessarily have been the production of high culture and abundant food, and that a continuance of the same measures which raised it to its highly improved state must be necessary to prevent its receding, in successive generations, from that excellence;" the cause of his Persian Melons deteriorating became apparent, and he found that by bringing the cultivation of the plants to a state of great perfection, he succeeded completely in rendering the original quality hereditary, as long as those precautions were observed. No man was more successful in the cultivation of the Melon than Knight, and it is in the memory of many persons that the quality of his Sweet Melons of Ispahan has very rarely been equalled. The peculiar methods that he adopted appear to have been the complete and most careful preservation of the leaves from injury of whatever kind, the full exposure of their surface to light, and the augmentation of the ordinary warmth of a Melon bed by availing himself of the heat reflected from brick tiles with which his bed was paved. To such an extent was his care of the leaves carried that he would not allow even the watering to be performed "overhead," but he caused his gardener to pour water from a vessel

of proper construction upon the brick tiles between the leaves without touching them. (See various papers upon the Melon in the *Horticultural Transactions,* and especially that in vol. vii., p. 584.)

While, however, such are the general principles upon which the preservation of the peculiar qualities of the many races of cultivated annuals necessarily depends, it must be confessed that, according to report, there are circumstances upon which science can throw no light, and which, if correctly stated, depend upon conditions as yet unsuspected to exist. Of this class is the following, respecting the Brussels Sprouts Cabbage, given upon the authority of M. Van Mons.

"Much has been said of the disposition of this plant to degenerate. In the soil of Brussels it remains true, and I have lately observed it to do the same in Louvain; but at Malines, which is the same distance from Brussels as Louvain, and where the greatest attention is paid to the growth of vegetables, it deviates from its proper character after the first sowing; yet it does not seem that any particular soil or aspect is essential to the plant, for it grows equally well and true at Brussels, in the gardens of the town, where the soil is sandy and mixed with a black moist loam, as in the fields, where a compact white clay predominates. The progress of deterioration at Malines was most rapid; the plants raised from seed of the true sort, which I had sent there, produced the sprouts in little bunches or rosettes, in their true form; seeds of those being saved, they gave plants in which the sprouts did not form into little cabbages, but were expanded; nor did they shoot again at the axils of the stem. The plants raised from the seeds of these last mentioned only produced lateral shoots with weak pendant leaves, and tops similar to the shoots, so that in three generations the entire character of the original was lost. From a plant in the state last described, seed was saved at my request, and sent back to me. I had it sown by itself, and carefully watched the plants in their growth; I was not long in discovering that they retained the same character of degeneration they had assumed at Malines, and preserved it throughout the whole course of their growth, yielding pendu-

lous leaves with long petioles, and having no disposition to cabbage. I suffered these plants to run to seed at a great distance from my true sprouts, which the extent of my garden allowed me easily to do. The second sowing brought them back a good deal to their true character; the plants yielded small cabbages regularly at each axil, but not generally full or compact, and they did not shoot a second time, as the true sort does. I again suffered these to run to seed, using the same precaution of keeping them by themselves. I sowed the seed, and this time the plants were found to have entirely recovered their original habits, their head, and rich produce." (*Hort. Trans.*, iii. 197.)

I continue to quote this passage for the sake of exciting attention to the subject, but it stands so entirely alone that it has probably arisen in some mistake. At all events it is now ascertained that the quality of English-saved Brussels Sprouts seed is fully equal to that from Brussels itself, as has been conclusively shown by Mr. Judd, a skilful gardener in Southill Gardens, near Biggleswade.

It has been often asserted that propagation by seed is the only natural process of multiplication, and that by propagation by division the races of plants wear out; that when a tree or other perennial plant becomes unhealthy from old age, all the offspring previously obtained from it by cuttings in all parts of the world becomes unhealthy too. Is such a doctrine a reasonable inference from known facts? or is it forced upon us by evidence although not deducible from mere reason? This is an important question, to a laboured advocacy of which pamphlets and newspapers have been abundantly brought into requisition. The subject has been already adverted to in these pages; it is now necessary to examine it more carefully.

The species of plants, like those of animals, appear to be eternal, so far as anything mundane can deserve that name. There is not the smallest reason to suppose that the Olive of our days is different from that of Noah; the *Asa dulcis* stamped upon the coins of Cyrene still flourishes around the site of that ancient city; and the Acorns figured among the sculptures of

Nimroud seem to show that the same Oak now grows on the mountains of Kurdistan as was known there in the days of Sardanapalus. There is not the slightest evidence to show that any species of plant has become extinct during the present order of things. All species have continued to propagate themselves by seeds, without losing their specific peculiarities; some appointed law has rendered them and their several natures eternal.

It would seem moreover that, with the exception of annuals and others of limited existence, the lives of the individual plants born from such seed would be eternal also, if it were not for the many accidents to which they are exposed, and which eventually destroy them. Trees and other plants of a perennial nature are renovated annually—annually receding from the point which was originally formed, and which in the nature of things must perish in time. The condition of their existence is a perpetual renewal of youth. In the proper sense of the word decrepitude cannot overtake them. The Acorus creeps along the mud, ever advancing from the starting point, renews itself as it advances, and leaves its original stem to die as its new shoots gain vigour; in the course of centuries a single Acorus might creep around the world itself, if it could only find mud in which to root. The Oak annually forms new living matter over that which was previously formed, the seat of life incessantly retreating from the seat of death. When such a tree decays no injury is felt, because the centre which perishes is made good at the circumference, over which new life is perennially distributed. But inevitable accidents interfere, and trees are prevented from being immortal.

Species, then, are eternal; and so would be the individuals sprung from their seeds, if it were not for accidental circumstances.

No reasonable person now pretends that the species of plants disappear. It is alleged, on the contrary, that seeds renew the languid vigour of a species as often as they are sown; and that if an unhealthy plant is multiplied from seeds the immediate offspring becomes healthy. It is also said that multiplication by seed is the only natural mode of propagation known among

plants, and that all other kinds of increase are artificial, and lead to debility.

It would, we think, be difficult to find an hypothesis more entirely at variance with notorious facts. That propagation by seed is *a* natural method of multiplication is doubtless true; but to say that no other natural means exist is absurd. The Sugar-cane is rarely propagated by seeds; its natural mode of propagation is by the stem, which when blown down by the storm emits roots at every joint. Of this natural property man has availed himself as a means of artificially extending the plant. The Tiger Lily naturally propagates itself by bulbs, formed in the bosom of its leaves; we never saw it form a seed. The Strawberry has been more propagated by its runners than by its seeds; and where do we find any signs of debility there? The Jerusalem Artichoke was introduced before the year 1617; for nearly two centuries and a half it has increased itself entirely by tubers, and never by seed. Couch Grass increases chiefly by its creeping roots; we wish we could adduce this, at least, as one instance of failing vigour in a plant whose seeds are but little yielded. It therefore is not true that plants, multiplied much or wholly by other means than seeds, become on that account unhealthy. Every gardener knows that his Achimenes are principally multiplied by little scaly bodies resembling tubers, and that these are formed in such abundance as to render seed unnecessary. In short, the denial of this could only arise from an entire unacquaintance with common facts. Such examples sufficiently show that Nature does provide other means of propagating plants than seeds, and that tubers are one of those means. The Hyacinth and the Garlic propagate naturally, not only by seeds, but also by the perpetual separation of their own limbs, known under the name of bulbs, their bulbs undergoing a similar natural process of dismemberment; and so on for ever. The Potato plant belongs to a similar class. Another plant bends its branches to the ground; the branches put forth roots, and, as soon as these roots are established, the connection between parent and offspring is broken, and a new plant springs into independent existence. Man turns this property to account

by artificial processes of multiplication; one tree he propagates by layers, another by cuttings planted in the ground. Going a step further he inserts a cutting of one individual upon the stem of some other individual of the same species, under the name of a bud or a scion, and thus obtains a vegetable twin.

It is not contended, for there is nothing to show, that these artificial productions are more short-lived than either parent, provided the constitution of the two individuals is in perfect accordance. There is not the smallest evidence—it has not been even conjectured—that if a seedling Apple-tree is cut into two parts, and these parts are reunited by grafting, the duration of the tree will be shorter than it would have been in the absence of the operation. No one indeed alleges that the Garlic of Ascalon has only a short life, although it has been propagated by sub-division from the time when it bore the name of Shummin, and fed the labourers at the Pyramids; nor do we know that the bulb-bearing Lily is supposed to have less inherent vigour than if it were multiplied by seeds instead of bulbs.

Seeds, however, are said in all instances to produce healthy plants. But this, like the previous assertions, will not bear exact investigation. The health of a seedling depends upon that of the seed. Under no circumstances will unhealthy seed yield vigorous offspring in the first generation; this is proved every day by what comes from grain debilitated by age. And there cannot be found a gardener, of any large experience, who does not know that seedlings will exhibit every diversity of constitution from health to decrepitude. This has been strikingly shown in the case of the Potato, which, when attacked by disease, in 1845, was said to be the victim of degeneracy, and to require renewal by fresh seed-sowing. Attempts were made in all directions to carry out this idea, and large quantities of seedling potatoes were raised. Among them great diversity of vigour and other qualities was, as usual, observed; some were much more healthy than others, as was always the case; but the evidence thus obtained failed to support the hypothesis that renewal by seed would prevent disease. On

the contrary, the seedlings were often more prone to disease than their parents.

But although it cannot be said that species wear out or degenerate, whatever their mode of propagation, it is confidently asserted that varieties, themselves artificial productions, obey another law, and that they do in fact perish from gradual loss of vitality. Passing by the objection that nobody has yet been able to show how what is called a species among plants really differs from what is called a variety, a very little examination appears to negative the idea of a degeneracy of race being any part of the System of the Universe.

Some maintain that vegetable, like animal life, has its fixed periods of duration, and that there is a time beyond which the debility incident to old age cannot be warded off; and this is true, so far as individuals are concerned. But it is to confound individuals with races to infer from this that all the cultivated races of plants require to be incessantly renewed by seed, in the absence of which precaution they gradually become unhealthy, and unfit for cultivation. It is thought that although the wild Potato possesses indefinite vitality, yet that the varieties of it which are brought into cultivation pass their lives circumscribed within very narrow limits; and the same doctrine has been held concerning fruit-trees.

The first person who proposed this theory was the late Thomas Andrew Knight, who, in the latter part of the last century, finding that the orchards of Herefordshire no longer contained healthy trees of certain varieties of Apple, which were said to have flourished fifty years before, and failing in his attempt to restore health to such varieties by grafting, assumed that old age had overtaken them, and that they were incurable. Thence he extended the theory to all other plants; and here and there writers on vegetable physiology, rather out of respect to Mr. Knight's great name than from any correct examination of the facts for themselves, have blindly adopted his views. But reason and evidence are alike opposed to the conclusion, which seems to have sprung out of a mistaken application of the laws of animal life to that of vegetables, and a desire to push analogy beyond its proper limits.

All who understand the nature of plants, and the manner in which they grow, and have witnessed that incessant renewal of their vitality with which Providence has so wonderfully endowed them, would hesitate to adopt Knight's views except in the presence of facts capable of no other possible interpretation. No physiologist can separate the nature of what gardeners call varieties (of course mules are not here included), from that of a wild race. In their intrinsic qualities they are the same. It can make no difference in the nature of a plant whether it is sown by a gardener or by winds, birds, animals, or other agents. The Oak which springs up in a forest is not in the smallest physiological particular different from that which rises from the bed of a nurseryman. The Cabbages which load the waggons of a market gardener are in their essence the same as those which sprout forth from the sea-beaten cliffs of the ocean. They may be greener or redder, more succulent and larger; but they are physiologically the same. We therefore must dismiss from our argument the word variety, which only leads to a confusion of ideas.

Among plants, as among animals, there are ephemeral and perennial species. The butterfly perishes in a few hours; nothing can defer the arrival of that early death which is the portion of such beings. Man, on the contrary, is endowed with a longevity the limit of which is hardly definable. In plants we have annuals, biennials, and perennials, to the last of which belong all trees and bushes. Now, wild perennial plants, whether woody or herbaceous, whether forming a trunk or a mere permanent root, have never yet been shown by any trustworthy evidence to be subject to decrepitude, arising from old age. On the contrary, every new annual growth is, as has just been stated, an absolute renewal of their vitality, in the absence of disturbing causes. Hence the enormous age at which trees arrive. A thousand years is still youth to a forest-tree which no accident has injured; and there is no intelligible reason why it should not, if guarded from violence, continue to grow to eternity. Travellers believe that they have found, in the forests of Brazil, trees that were seedlings in the age of Homer. There seems to be no doubt that the Wellingtonias, now

growing in California, were born in the days when Mahomet was in full career.

It is true that plants do in reality perish commonly without attaining any such longevity; and that constitutional feebleness is notoriously one of the accompaniments of advancing age. But this arises from external, not intrinsic, causes. The soil which surrounds them is exhausted, their roots wander into uncongenial land, water in unnatural excess is introduced, the food they require is withheld, violence rends them, men mutilate them, severe cold disorganizes them, and these and other causes produce *disease*, which may end in death. But this is very different from dying of mere old age; and for practical purposes it is material to draw the distinction.

If no evidence exist to show that wild plants suffer from mere old age, we cannot admit such a property to be incident to those which are cultivated.

Nevertheless, what are called facts, have been adduced to prove that if plants do not die of old age in a wild state, yet that they incontestably do wear out when artificially multiplied by division. In opposition to this it would seem to be sufficient to quote the White Beurré Pears of France, which French writers assure us have been thus propagated from time immemorial, and which exhibit no trace of debility; or the Jerusalem Artichoke already named; or the cultivated Vines of which the very varieties known to the Romans have been transmitted by perpetual division, and without deterioration or decrepitude, to our own day. The *Vitis præcox* of Columella is admitted by Dr. Henderson, on the authority of the most trustworthy writers, to have been the *Maurillon* or *Early Black July* Grape of the present day; the *nomentana* to have been the German *traminer;* the *græcula* the modern Corinth or Currant; and the *dactyli* our *Cornichons* or *Finger* Grapes. The oldest known variety of Pear is the autumn Bergamot—believed by Pomologists to be identically the same fruit cultivated by the Romans in the time of Julius Cæsar,—that is to say, the variety is nearly two thousand years old.

Still it is affirmed that *some* cultivated plants have really worn out. The Redstreak, the Golden Pippin, and the Golden

Harvey Apples are among the number quoted. The first of these is little known to us, and we have no evidence about it; but the Golden Pippin and Golden Harvey are certainly not capable of being employed in support of Knight's theory. Both are to be found in various places at this moment in as perfect health as they ever enjoyed. In the United States we are assured by American writers that all our diseased European Apples and Pears exist in the highest vigour. The Golden Pippin is among the most healthy Apples of Madeira: the Golden Harvey is in many good gardens. Of the former, healthy trees were many years since shown to exist in Norfolk; in warm dry places it had no particular appearance of suffering. Recruited by the fine climate of France, the Golden Pippin has been received back to this country in as healthy a state as ever, and is now growing in the garden of the Horticultural Society. The old Nonpareil was well known in the time of Queen Elizabeth; in cold places it cankers, and no doubt always has cankered; but what can be more healthy than that variety in favourable places? One writer infers because the Gooseberry growers of Lancashire find the weight of their fruit diminishes "after the varieties have been cultivated some time," that therefore these varieties are dying of old age, and he has expended no inconsiderable quantity of learning in attempting to fit this speculation to the Potato. So impressed, indeed, is he with a conviction of its truth, that he, as well as others, recommends people to be sent to Peru, or wherever else the Potato grows wild, in order to get seeds and tubers of vigorous wild plants. But what is called evidence breaks down wherever it is examined; and this part of the argument about the wearing out of races, proves to be baseless.

"Certain French writers, about this time, gladly seized Knight's theory as an explanation of the miserable state into which the fine old sorts of Pears had fallen about Paris, owing to bad culture and propagation. They sealed the death-warrant, in like manner, of the Brown Beurré, Doyenné, Chaumontel, and many others. Notwithstanding this, and that ten or fifteen years have since elapsed, it is worthy of notice that the repudiated Apples and Pears still hold their place among all the best cultivators in both England and France. Nearly half the Pear-trees annually introduced into this country (the United States) from

France are the Doyenné and Beurré. And the 'extinct varieties' seem yet to bid defiance to theorists and bad cultivation."—*Downing.*

"We may easily conceive," says De Candolle, "that every cultivated variety owed its origin to some special circumstance, which once occurred, and but once. In such a case the variety has been multiplied by division, and every plant so obtained from it has been a portion of the same individual; which accounts for their all being exactly like each other. An identity of origin in all the plants of the same variety has led some physiologists to imagine that these varieties or fractions of an individual might die of old age. But it is difficult to admit, upon such a single fact, an hypothesis opposed to all other facts. That varieties will last, so long as man takes care of them, appears to be proved by many of them having been preserved from the most remote periods. But it is also certain that negligence will cause some to disappear, just as accident or industry brings others into existence." —(*Phys. Végétale*, p. 731, somewhat abridged.)

Although an examination of evidence leads to the conclusion, that the wearing out of the races of plants by old age does not occur, yet it is not intended to deny the accuracy of the statements made by some recent writers on the subject. We may admit their facts, but reject their reasoning, and the inferences they would have us draw.

In *The Florist's Directory* by James Maddock, 1792, are the following observations:—"The constitution of Anemones undergoes considerable changes with age, which is, perhaps, in a greater or smaller degree, the case with all other vegetables. The Anemone will not last more than twelve or fifteen years without degenerating, unless it be frequently removed to a different soil and situation; nor will any removals protract or prolong its existence more than thirty or forty years. It generally blows in its greatest degree of perfection from the fifth to the tenth or twelfth year, after which it becomes gradually smaller and weaker, and if the flower was originally very full and double, with age it loses that property; the petals diminish in number, become small and irregular, and finally the sort perishes. It has more than once occurred that the same sort, although in possession of many persons, residing at remote distances from each other, has been entirely lost in one season, without the possibility of accounting for the fact in any other manner than the above." In a foot-note the

author observes—"The Ranunculus will last about twenty or twenty-five years in perfection, after which it degenerates and perishes." It does not appear that this period of duration is confined only to seminal varieties of vegetables, for although the original wild parent still continues to flourish, as it has done since its creation, yet there is no evidence to show that the wild individuals are each more long-lived than those which are domesticated. The fact appears to be that Anemones and Ranunculuses are very short-lived species. In a wild state they are annually renewed by self-sowing; in gardens they enjoy a forced extension of vitality secured by artificial means, which are, however, temporary in their effect, just as annuals may be made to live for two or three years by similar means.

In like manner when we are told that grafts taken from an old diseased fruit-tree produce young diseased plants, as is undoubtedly the case, it is not to be inferred that its race is wearing out. The only inference which the fact justifies is that when an individual becomes diseased, a limb from that individual, if transferred to another plant, carries its disease with it. To prove the theory of degeneracy it is necessary to show, what has never yet been done, that no care can preserve a perennial variety from decrepitude.

In the case of the Apple-trees and Gooseberry-bushes lately adverted to this seems to be the true explanation of the facts relating to them. A tree, from some cause or other, becomes unhealthy; a piece cut from it and put upon another tree carries its disease with it; again divided, the disease is again propagated, and this will go on as long as the unhealthy plants remain exposed to the influences which originally caused their bad health. But change the circumstances, place the plants under more favourable circumstances, keep off the cause of the evil, and the evil will gradually disappear, as has actually happened to our diseased fruit-trees when carried to better climates than our own.

The best recent statement, with which I am acquainted, of facts in favour of wearing out will be found in a paper communicated to the *Gardeners' Chronicle* (1853, p. 372) by Mr. Masters of Canterbury.

CHAPTER XVIII.

ON THE IMPROVEMENT OF RACES.

WHAT has been stated in the preceding chapter, concerning the preservation of the races of domesticated plants, is in some measure applicable to their improvement; because the very means employed to preserve those peculiarities of habit, which render them valuable, will, from time to time, be the cause of still more valuable qualities making their appearance. There are, however, other points of great importance on which the gardener has dependence.

Sudden alterations in the quality of seedling plants often occur from no apparent cause, just as those accidental changes, called "sports," in the colour or form of the leaves, flowers, or fruit, of one single branch of a tree, occasionally break out, we know not why. Of these things, physiology can give no account; but it is certain that, when such sports appear, they indicate a violent constitutional change in the action of the limb thus affected, which change may be sometimes perpetuated by seed, and always by propagation of the limb itself where propagation is practicable. It is possible that even new forms of shrubs might be procured by keeping these facts in view, and that climbers might be deprived of their climbing habits, for it is known that the handsome evergreen bush called the Tree Ivy, which grows erect, with scarcely the least tendency to climb, has been procured by propagating the fruit-bearing branches of trees of considerable age.

A sport is a *mutatio per saltum*, or, a sudden change of one thing into another, different in some very striking respect, as

when a Peach-tree produces a smooth fruit (a Nectarine) amon its own downy brood. These sudden changes seem to b essentially different in their nature from the gradual alteration which cultivation brings about in all plants; they are violen transformations produced by unknown causes, and in whic there is a natural tendency to preserve the altered condition Some examples and their known results will make thi plainer.

The annual Clarkia pulchella bears naturally a purple flower Unexpectedly, among other seedlings, a plant appeared in whicl the flowers were pure white—a vegetable Albino. That was sport. The seed was saved and sown; the produce consiste of many purple and many white-flowering individuals. Th purples which had lost the new tendency were removed, an seed again saved from the pure whites; the next batch o seedlings was much more white than purple; the next batcl was all white, and thus the original sport was fixed.

When the Provins Rose produced a branch on which th flowers were buried among those glandular expansions of th calyx and its footstalk which we call mossiness, the first Mos Rose was born:—that again was a sport.

When some Celosia suddenly formed its flowers upon thickened, flattened (fasciated) stalk, and they became mor crowded than usual, we had a Cockscomb, and that again was sport. The plant thus changed, by whatever cause, had gaine a constitutional tendency to grow in the cockscomb or fasciate manner; by repeatedly saving seed from the most fasciate and the dwarfest seedlings, that which was at first a mer tendency or predisposition became as fixed a constitutiona character as was acquired by the greyhound when he firs became a new variety of some other kind of dog. Thi fasciated character was at first a mere monstrosity, such as w see around us here and there in a great variety of plants i which no one has yet thought of fixing the habit. If it ha a tendency to disappear under neglect, as those who buy cheap seeds know that it has, so, on the other hand, it has also tendency to increase under skilful management, as was show by Mr. Andrew Knight when he, by one single effort, brough

a Cockscomb plant to measure eighteen inches across and only seven inches high.*

An analogous change is that represented at Fig. XCVII., which is not at all uncommon in the Canterbury Bell, whose flowering stem becomes fasciated, and the flowers run together

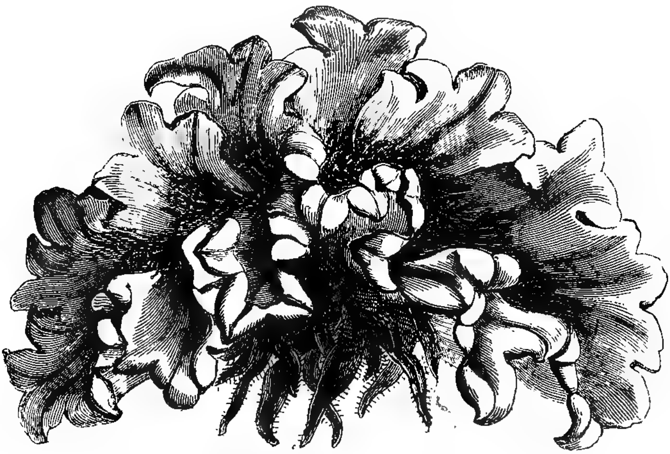

Fig. XCVII.—Monstrous Canterbury Bell.

into a magnificent crescent-shaped head. Gardeners have never attempted to fix this striking character, and yet it might perhaps be secured as the Cockscomb.

Mr. Salter, of Hammersmith, observed among his seedling Dahlias one which produced a number of green scaly flower-heads, but no perfect flowers. This was propagated and every plant was covered with similar heads of scales. All the plants were vigorous, but there was not a single perfect flower-head upon any one of them, so that the sport became immediately fixed. (See Fig. XCVIII.)

M. Esprit Fabre observed that a kind of wild Grass (*Ægilops ovata*) was subject to a sport (*Æ. triticoides*). Of that sport he sowed the seeds, and he found that while on the one hand there

* This was in 1820. A drawing of this specimen hangs in the library of the Horticultural Society. The manner in which the experiment was conducted is described in the *Hort. Trans.*, vol iv., p. 321.

was no disposition to return to its original form, there was on the other a decided tendency to sport still more. Of that tendency he availed himself with admirable patience. Year by year the change went on—but slowly. Little by little one part altered or another. The hungry grain grew plumper; the flour in it increased; its size augmented. The starved ears formed other spikelets; the spikelets at first containing but two flowers at last became capable of yielding four or five. The straw stiffened, the leaves widened, the ears lengthened, the corn softened and augmented, till at last Wheat itself stood revealed, and of such quality that it was not excelled on the neighbouring farms.

Fig. XCVIII.—Monstrous Dahlia.

It is, in fact, through attention to sports that many of the most striking of our flowers and fruit have been obtained. A single dwarf Larkspur sports by chance to double; the seeds of the sport are saved carefully and sown; three-fourths of the seedlings are single, but a few are double; the first are thrown away, the best of the second are saved for seed, and the second crop of seedlings comes truer. Thus arise the race of double Larkspurs. A double Larkspur next sports to a stripe, that is

to say, bands of red or of violet appear upon the pale ground of the petals of a few flowers; these flowers are marked, the seed is saved, and so begins the breed of what are called Uniques, at one time the pride of the flower-garden, though now discarded for newer favourites. In the same way, first came Camellias, Chrysanthemums, and others. The old purple Chrysanthemum accidentally sported to buff: the buff branch was struck, proved true to its new nature, and became the ancestor of a race of other buffs. The colour of a red Camellia "breaks;" red streaks appear in the flowers of a sporting branch; that branch is separated, and grafted upon a stout stock; on goes the sportive branch, retains its tendency, produces striped flowers all the better for the new blood infused into them, and the tendency is fixed; skilful gardeners cut it limb from limb, and every mutilated morsel starts into life another variegation.

It is the same with vegetables; a wild Carrot accidentally found in cultivated ground refuses to run to seed, but builds up a root stouter than any Carrot had before. The watchful eyes of a gardener remark the change; the changeling, still a sport, flowers at last; its precious seeds are saved, and committed to still richer ground. Nine-tenths of the seedlings run back to the wild form—but a very few prove obedient to the will of man, shake off their savage habits, refuse to flower till the second year, spend their autumn and winter in the further enlargement of their roots, then rise up into blossom invigorated by six months' additional preparation, and yield other seeds, in which the fixity of character, or habit of domestication, is still more firmly implanted. And thus begins the race of Carrots.

Nectarines, Pears, Peaches, Plums, and other valuable fruits, must be supposed to have in numerous instances derived their origin from similar circumstances; they were far more the children of accident than design, and we see to what they have come.

Gardeners, then, should keep a watchful eye upon every tendency to sport, which they may remark among the plants entrusted to their care. The sports, however unpromising,

should be made the subject of repeated experiment; year after year seeds should be saved, seed-beds "rogued," and attempts made to secure fixity of character. If they end in nothing, as they often will, such experiments have the advantage of also costing nothing; but if they lead to a good result a permanent gain is secured.

The tendency of plants to variation being so general, and in many cases so remarkably great, we may reasonably expect that by taking proper advantage of it we may obtain much, if not all that we would wish. "We see every day the wide range of seminal diversities in our gardens," said Dean Herbert, in the *Journal of the Horticultural Society*. "We have known Dahlias from a poor single dull-coloured flower break into superior forms and brilliant colours; we have seen a Carnation, by the reduplication of its calyx, acquire almost the appearance of an ear of Wheat, and look like a glumaceous plant; we have seen Hollyhocks in their generations branch into a variety of colours, which are reproduced by the several descendants with tolerable certainty. We cannot, therefore, say that the order to multiply after their kind meant that the produce should be precisely similar to the original type; and, if the type was allowed to reproduce itself with variation, who can pretend to say how much variation the Almighty allowed? Who can say that this glorious scheme for clothing the earth was not the creation of a certain number of original plants, predestined by Him in their reproduction to exhibit certain variations, which should hereafter become fixed characters, as well as those variations which even now frequently arise, and become nearly fixed characters, but not absolutely so, and those which are more variable, and very subject to relapse in reproduction?"

But we are by no means destitute of the power of procuring, with some certainty, improved varieties, by an application to practice of physiological principles. In the last chapter has been shown the importance of securing the production of seed by plants in the most healthy state possible, because a robust parent is likely to afford a progeny of similar habits to itself. In annuals, however, this is apparently restrained within narrower limits than in woody plants, from the great difficulty of fixing a new peculiarity in the former, and the facility with which it may be effected in the latter case, by means of buds, cuttings, grafts, and similar modes of propagation. The object of the scientific gardener who desires to improve the varieties

of plants upon principle will be, then, by artificial means, to bring the parent from which seed is to be saved as near as possible to that state at which he desires the seedling to arrive.

It is known that the abstraction of fruit and flowers augments the vigour of the branches, or of the parts connected with them, and that the removal from the former of any part which takes up a portion of the food employed in the support of the flowers increases their efficiency. Thus those varieties of the Potato, which will neither flower nor fruit otherwise, may be made to do both by stopping the development of tubers; and, on the other hand, the size and weight of the tubers themselves are increased by preventing the formation of flowers and fruit. The course, then, to take, in obtaining the largest possible tubers in a new variety of the Potato, would be, in the first place, to effect that end temporarily, but during several successive seasons, by abstracting all the flowers and fruit, and by such other means as may suggest themselves; and then to obtain the most perfect seed possible by a destruction of the tubers during the season when seed is finally to be saved. Mr. Knight found, in raising new varieties of the Peach, that, when one stone contained two seeds, the plants these afforded were inferior to others. The largest seeds, obtained from the finest fruit, and from that which ripens most perfectly and most early, should always be selected (*Hort. Trans.*, i. 39); and, in his incessant efforts to obtain new varieties of fruit of other genera, he had reason to conclude that the trees, from blossoms and seeds of which it is proposed to propagate, should have grown at least two years in mould of the best quality; that during that period they should not be allowed to exhaust themselves by bearing any considerable crop of fruit; and that the wood of the preceding year should be thoroughly ripened (by artificial heat when necessary) at an early period in the autumn; and, if early maturity in the fruit of the new seedling plant is required, that the fruit, within which the seed grows, should be made to acquire maturity within as short a period as is consistent with its attaining its full size and perfect flavour. Those qualities ought also to be sought in the parent fruits, which are desired in the offspring; and he found that the most perfect

and vigorous progeny was obtained, of plants as of animals, when the male and female parent were not closely related to each other. (See the *Horticultural Transactions*, i. 165.)

There are no processes known to the cultivator so efficacious in producing new varieties as that adverted to in the last paragraph, that is to say, muling or cross-breeding; and it is to these operations, more than to anything else, except accident, that we owe the beauty and excellence of most of our garden productions; more, however, I think, to cross-breeding than to muling. By cross-breeding is meant the intermixture of varieties; by muling or hybridising, that of species. It was by the first of these processes that have been so greatly multiplied and improved our fruits for the dessert, and the gay flowers that adorn our gardens. The Pelargonium, the Calceolaria, the Dahlia, the Verbena, and a thousand others—what would they be, but simple wild flowers, without the power of man exercised in this way? "To the cultivators of ornamental plants," says Mr. Herbert,* "the facility of raising hybrid varieties affords an endless source of interest and amusement. He sees in the several species of each genus that he possesses the materials with which he must work, and he considers in what manner he can blend them to the best advantage, looking to the several gifts in which each excels, whether of hardiness to endure our seasons, of brilliancy in its colours, of delicacy in its markings, of fragrance, or stature, or profusion of blossom; and he may anticipate, with tolerable accuracy, the probable aspect of the intermediate plant which he is permitted to create: for that term may be figuratively applied to the introduction into the world of a natural form which has probably never before existed in it. In constitution the mixed offspring appears to partake of the habits of both parents; that is to say, it will be less hardy than the one of its parents which bears the greatest exposure, and not so delicate as the

* See much the most valuable and practical accounts of cross-breeding and muling which have been yet published in regard to horticulture, in the *Amaryllidaceæ* of Dean Herbert, p. 335, et seq., and in the same author's papers published in the *Journal of the Horticultural Society*, vol. ii. pp. 1 and 81. See also a most important memoir upon the same subject by Gærtner, translated by the Rev. M. J. Berkeley, in the same work, vol. v., p. 156, and vol. vi., p. 1.

other: but, if one of the parents is quite hardy, and the other not quite able to support our winters, the probability is, that the offspring will support them, though it may suffer from a very unusual depression of the thermometer, or excess of moisture, which would not destroy its hardier parent."

"In few characters is the influence of muling more striking than in the size and colour of blossoms. In many closely allied species, which differ but little in habit or foliage, the colour of the corolla is of great importance. In a wild state it is for the most part constant, and is often indicative of distinct groups or species. In other groups, on the contrary, it is extremely variable, and is notably different at different periods of growth. Where, however, colour is the most constant and distinctive, union is often practicable, and in general the consequence of hybridisation is a complete derangement of the laws on which such constancy of hue depends. Neither are the hues resulting from the union necessarily intermediate. Blue and yellow, for instance, do not produce green, as is proved by Verbascum phœniceum and phlomoides. Gladiolus cardinali-blandus exhibits the less brilliant hue of the male parent rather than the splendour of the mother; and in some cases the tone of colour of one of the parents is exhibited under a more brilliant tint, as in Nicotiana suaveolenti-glutinosa.

"Little has been done at present in the hybridising of cereals, but Herbert believed that more useful varieties than at present exist of Wheat, Oats, and Barley, might be produced by combining the fruitfulness of one variety with the hardiness of another, to both of which might be added the thin skin and consequent superior weight of a third. Knight's wrinkled Peas are a proof of what may be done by hybridising, and it is probable that much might be effected in Beet, Cabbages, Carrots, Celery, &c., by especial attention to this point.

"Amongst woody plants also there are instances of peculiarly luxuriant growth, such as Lycium barbato-afrum. Varieties therefore might be produced, of much more rapid growth, which for some purposes might have their value, though the quality of the timber would probably suffer.

"Another peculiarity of hybrids is their precocity, of which advantage may be taken where early fruit is desirable, or where the summers are not long enough to ripen the later fruit.

"A very important quality of hybrids is also their power in very many cases of enduring a greater degree of cold than the pure species from which they are derived, and hence the acclimatisation of many useful plants by means of hybrid forms or varieties may be effected. The hybrids, for instance, of Nicotiana are far less susceptible of frost than their pure parents, a circumstance of very great importance if the cultivation of Tobacco were to be materially extended.

"The great fruitfulness of many hybrid varieties is also a material point as regards their useful qualities, especially in orchards and vineyards, and where ornament, effect, or what the Germans call æsthetic botany in its various branches is concerned, hybrids supply an endless subject of experiment.

"And lastly, the longer duration of many hybrids and their more persistent larger blossoms make them especial objects of favour and delight.

"The great difficulty in the way of experiment is the frequent want of fertility in the seeds of hybrids, and their tendency to wear out, wherever there is a possibility of impregnation from neighbouring varieties.

"The simple hybrid reverts to the mother type by repeated impregnation with the maternal pollen, or when the paternal pollen is applied, goes forward to the type of the father: the conversion of the mother into the father is, however, seldom synchronous with the contrary change. Nicotiana rustica was changed in this manner by Kölreuter into N. paniculata, and similar changes have been effected by others.

"When hybrids are impregnated a third or fourth time with the pollen of the original male parent, they gradually approximate more and more to the male type, and at last are not distinguishable from it, except perhaps in a less degree of fertility, though this negative sign vanishes sooner or later. There is no certainty as to the number of successive impregnations necessary to produce this complete change. Different species exhibit in this respect very different results. Nicotiana rustico-paniculata, even in the fifth degree, is occasionally completely sterile either as to the stigma or anthers, but especially as regards the latter.

"The tendency of varieties to return to the maternal type seems to be a peculiarity general to the vegetable kingdom, especially if left to themselves, free from the trammels of cultivation. This return, however, in the second generation of simple hybrids, or of paternal mules of the second degree, is always effected by fructification, and not by any other mode of propagation. It seems also more easy than the approach to the paternal type, though in neither case does it take place to a considerable extent, nor does it take place in all genera, and when it does occur the produce is less fertile."—*Gærtner.*

The following are the *practical* instructions for hybridising given by Mr. Isaac Anderson, one of our most skilful operators in this way:—

"To those who would attempt the hybridising or cross-breeding of plants, I will now offer some suggestions for their guidance. It is an essential element to success that the operator be possessed of indomitable patience, watchfulness, and perseverance. Having determined on the subjects on which he is to operate, if the plants are in the open

ground, he will have them put into pots, and removed under glass, so as to escape the accidents of variable temperature—of wind, rain, and dust, and, above all, of insects. A greenhouse fully exposed to the sun is best adapted for the purpose, at least as regards hardy and proper greenhouse plants. Having got them housed, secure a corner where they are least likely to be visited by bees or other insects. The plants which are to yield the pollen, and the plants which are to bear the seed, should be both kept in the same temperature; but where this cannot be managed, pollen from an outside plant, in genial summer weather, may be used, provided it can be got; for there is a class of insects which live exclusively on pollen, and devour it so fast after the pollen vessels open, that, unless the plant is under a hand-glass (which I would recommend), it is scarcely possible to get any pollen for the required purpose. To secure against chances of this nature, a sprig with opening bloom may be taken and kept in a phial and water inside, where it will get sufficient sun to ripen the pollen. But here, too, insects must be watched, and destroyed if they intrude. An insect like, but smaller, than the common hive bee, which flits about by fits and starts, on expanded wings, after the manner of the dragon-fly, is the greatest pest, and seems to feed exclusively on pollen. The hive bee, the humble bee, and wasp, give the next greatest annoyance. All these may be excluded by netting fixed over apertures from open sashes or the like. Too much care cannot be bestowed on excluding these intruders, whose single touch, in many cases, might neutralise the intended result; for the slightest application of pollen native to the parent plant is said by physiologists to supersede all foreign agency, unless, perhaps, in the crossing of mere varieties; and the truth of this observation consists with my own experience. Without due precaution, now, the labour, anxiety, and watchfulness of years may issue in vexation and disappointment. As a further precaution still, and to prevent self-fertilisation, divest the blooms to be operated on not only of their anthers, but also of their corollas. Remove also all contiguous blooms upon the plant, lest the syringe incautiously directed, or some sudden draft of air, convey the native pollen, and anticipate the intended operation. The corolla appears to be the means by which insects are attracted; and though, when it is removed, the honey on which they feed is still present, they seem puzzled or indifferent about collecting it; or if, haply, they should alight on the dismantled flower (which I never have detected), the stigma is in most cases safe from their contact. It will be some days—probably a week or more, if the weather be not sunny—ere the stigma is in a fit condition for fertilisation. This is indicated in many families, such as Ericaceæ, Rosaceæ, Scrophularinæ, Aurantiaceæ, &c., by a viscous exudation in the sutures (where these exist) of the stigma, but generally covering the entire surface of that organ. In this condition the

stigma may remain many days, during which fertilisation may be performed: and this period will be longer or shorter as the weather is sunny, or damp or overcast. In certain families, such as the Malvaceæ, Geraniaceæ, &c., where the stigma divides itself into feathery parts, and where the viscous process is either absent or inappreciable by the eye, the separation of these parts, the bursting of the pollen, the maturity of the stigma, and all which a little experience will detect, indicate the proper time for the operation, sunny or cloudy weather always affecting the duration of the period during which it may be successfully performed. As to the proper time and season best adapted for such experiments, a treatise might be written; but here a few remarks must suffice. As for the season of the year, from early spring to midsummer I would account the best period; but, as I have just observed, I regard all cold, damp, cloudy, and ungenial weather as unfavourable. On the other hand, when the weather is genial, not so much from sun heat as at times occurs from the atmosphere being moderately charged with electricity, when there is an elasticity, so to speak, in the balmy air, and all nature seems joyous and instinct with life, this, of all others, is the season which the hybridist should improve, and above all if he attempt muling. The hybridist should be provided with a pocket lens, a pair of wire pincers, and various coloured silk threads. With the lens he will observe the maturity of the pollen and the condition of the stigma, whether the former has attained its powdery, and the latter (if such is its nature) its viscous condition. If he find both the pollen and the stigma in a fit state, he will, with the pincers, apply an anther with ripened pollen, and by the gentlest touch distribute it very thinly over the summit of the stigma. The operation performed, he will mark it by tying round the flower-stalk a bit of that particular coloured silk thread which he wishes to indicate the particular plant which bore the pollen, and at the same time tie a bit of the same silk round the stem of the latter, which will serve till recorded in a note-book, which should be kept by every one trying experiments on a large scale.

"It is quite unnecessary to offer any directions as to the results to be effected. If it is desired to reproduce the larger, finer formed, or higher coloured bloom of a plant having a tall, straggling, or too robust a growth, or having too large or too coarse foliage in a plant without these drawbacks, I need not suggest to select, in another species of the same family, a plant of an opposite character and properties—say of dwarf compact growth, handsome foliage, and free flowering habit; and if such can be obtained, work with it, making the latter the seed-bearer. Or, if it be desirable to impart the fragrance of a less handsome kind to another more handsome, I would make the cross upon the latter. I cannot speak with certainty from my own experiments how far perfume may be so communicated; but I have some things far advanced to maturity to test it; and I entertain the hope that fragrance may not

only be so imparted, but even heightened, varied, and improved. Or if it be desired to transfer all, or any valuable property or quality, from a tender exotic species to a native or hardy kind, work upon the latter; for so far as constitution goes, I agree with those who hold that the female overrules in this particular. I would offer this caution to those who wish to preserve the purity of certain flowers for exhibition, especially those having white grounds, not to cross such with high coloured sorts. I once spoiled a pure white-bloomed Calceolaria for exhibition by crossing it with a crimson sort; all the blooms on those branches where the operation had been performed, being stained red, and not the few flowers merely on which the cross was effected. In this note, already too long, I cannot further illustrate my remarks, by recorded experiments in the various tribes upon which I have tried my hand; but I cannot leave the subject without inculcating, in the strongest manner, the observance of the rules I have laid down to prevent vexatious disappointments. If any doubts arise about the cross being genuine or effectually secured, let not the seeds be sown. Three, four, five, and even six years, must oftentimes elapse with trees and shrubby things ere the result can be judged of; and if eventually it prove a failure, or even doubtful, it is worse than labour lost, inasmuch as it may mislead. If there is no great departure from the female parent, the issue is to be mistrusted. It is singular, if well accomplished, how much of both parents is blended in the progeny. Gentlemen eminent as physiologists have read nature's laws in these matters a little differently from what my own humble experience has taught me, and assigned to the progeny the constitution and general aspect of the one parent, while they gave the inflorescence and fruit to the other. I have crossed and inverted the cross, and can venture to give no evidence on the point, except, perhaps, as to constitution, to which the seed-bearer, I think, contributes most. A well-managed hybrid should and will blend both parents into a distinct intermediate, insomuch so as to produce often what might pass for a new species. If the leaning be to one more than another, it is probably to the female, though this will not always be the case. Again, it is asserted that a proper hybrid—*i.e.*, one species which is crossed with another species, which is separate and distinct from it—will produce no fertile seeds. This does not accord with my observations. Dr. Lindley has remarked very justly (*Theory of Horticulture*, p. 69), 'But facts prove that undoubted hybrids may be fertile.' My hybrid, Veronica Balfouriana (an intermediate between V. saxatilis and V. fruticulosa), seeds, I would say, more abundantly than either parent; and the progeny from its self-sown seeds I find to be of various shades of blue, violet, and red, rising in my garden, some having actually larger, finer, and higher-coloured blooms than the parent bearing the seed; and I am familiar with the same result in other things. Yet I am far from

asserting fertility in the produce between two members of allied but distinct genera—such, for example, as in the Brianthus, which I have found to be unproductive, whether employed as the male or female parent. As above conjectured, its parents were far too remote in nature's own arrangement. The hybridist has a field before him ever suggestive of new modes of acting. He may try, as I have done, what may be effected under various tinted glass. My persuasion is that I effected from a pale yellow a pure white-grounded Calceolaria, by placing the plants under blue shaded glass, by which the sun's rays were much subdued. He may also apply chemical solutions to plants with ripening seeds. Nature, in producing, as it sometimes does, plants with blooms of colours opposite to those of the parent, must be governed by some law. Why may not this law be found out? For example, under what influence was the first white Fuchsia, the F. Venus Victrix, produced, the purest yet of all the race, and the source from which all the whites have been derived?"—*McIntosh's Book of the Garden.*

In the many successful attempts made by Mr. Knight to improve the quality of fruit-trees by raising new varieties, his method was to obtain crossbreds by fertilising the stigma of one variety of known habits with the pollen of another also of known habits. But, in doing this, his experiments were not conducted at random, and without due consideration; on the contrary, we learn from himself, that he was very careful in selecting the parents from which his crossbreds were obtained. He found that the general opinion, that the offspring of crossbred plants as well as crossbred animals usually presents great irregularity of character, is unfounded; and that if a male of *permanent habits*, and of course not crossbred, be selected, that will completely overrule the disposition to sport, "the permanent character always controlling and prevailing over the variable." He tells us that he usually propagated from the seeds of such varieties as are sufficiently hardy to bear and ripen their fruit, even in unfavourable seasons and situations, without the protection of a wall; because, in many experiments made with a view to ascertaining the comparative influence of the male and female on their offspring, he had observed in fruits, with few exceptions, a strong prevalence of the constitution and habits of the female parent. This, however, is the reverse of the result at which Dean Herbert had arrived in the very

great number of experiments performed by himself on that subject, he believing that the male parent generally influences the character of the foliage, and the female that of the flowers. (*Amaryllidaceæ*, p. 348, 377.) At a later period of his experiments he even ventured to say, "as far as I have observed, the prevailing disposition of crossbred vegetables seems to assimilate more to the male than to the female parent, though the appearance may possibly be sometimes the reverse, and often strictly intermediate; as far as I have seen, if we obtain a cross between a hardy and a tender species, the produce, where the male is hardy, will be much more hardy than where the female is hardy and the male tender. This is very important and very conspicuous in crossbred Rhododendrons." (*Journ. of Hort. Soc.*) It does appear to me that, in the majority of cases, Dean Herbert's opinion is the more correct of the two, yet I fear there is too little certainty in the results of hybridising to justify the establishment of any axiom upon the subject.

In the midst of many experiments conducted without exactness, from which no safe conclusion can be drawn, there are some which, in the hands of such men as the late Dean, seem to justify the inference, that in general the properties of the male parent will be most conspicuous in the hybrid. For example, he crossed the long-yellow-cupped common Daffodil, with the small red-edge-cupped Poet's Narcissus; and the seeds of the common Daffodil furnished a bulb with most of the attributes of the Poet's Narcissus. The same experimentalist also obtained out of a capsule of Rhododendron ponticum, inoculated by Azalea pontica, seedlings which had entirely the habit of the latter or male parent. In like manner the arborescent crimson-flowered Rhododendron altaclerense was raised from the seed of the dwarf pallid R. catawbiense hybridised by the arborescent crimson R. arboreum; and when the common scarlet Azalea, with its crimson flowers and narrow leaves, was inoculated at Highclere by Azalea pontica, Mr. Gowen found that its seeds produced plants much more like the male than the female parent. Exceptions, or apparent exceptions to this, no doubt exist, and hybrids could be found which are either half-way between their father and mother, or more like the mother than the father; but as far as any means of judging at present exist these would seem to be the exception and not the rule; and therefore the greater influence of the male may be taken as a tolerably safe guide in experiments upon this subject. Some highly interesting experiments, by M. Lecoq, upon muling Marvels of Peru, are on record. (*Gardeners' Chronicle*, 1853, p. 483.)

Hybrids were obtained between the species Mirabilis Jalapa and M. longiflora. A plant of the latter was crossed with the former, but not one fertile seed was obtained. From M. Jalapa fertilised with pollen of M. longiflora, some plants were raised which produced seed. The flowers were of various colours; and the roots of these hybrid plants were of enormous size—three and a-half feet in length. The general conclusion to which these experiments led was, that hybrids between species are exactly intermediate, at least in the case of the Mirabilis. But he arrives at the singular result that hybrids from hybrids do not follow this law, but become infinitely varied and far removed from their original type; that all hybrid plants are not sterile, and although they may produce seeds but sparingly, yet when the plants from these are crossed with their own parents, the plants resulting are of great fertility. This completely justifies the opinion that no absolute rules for judging of the effect of an experiment in muling have been yet discovered.

The conclusions of Gærtner as to this point are as follows:—

1. Various notions have existed, both in the animal and vegetable kingdom, with respect to the degree of influence which the sexes have in the production of hybrids: according to one authority, the male, in animals, giving origin to internal qualities, the female to external; to another, the former to the cellular system, the latter to the nervous, &c. Amongst plants, the difference of opinion is as great; but the truth appears to be, that no general rule can be laid down—in Digitalis the influence of the female parent being predominant, in Nicotiana that of the male, and the differences exhibited by individual species are no less decisive against any universal law. And this is no less true as to comparative degrees of fruitfulness. Indeed, the identity of the produce, when the sexes are reversed, is a sufficient proof of its non-existence.

2. When impregnation takes place between two pure species, it is an universal rule, "that the characters of the parents never remain pure and unaltered in the formation of the hybrid." In general every part of the new production is modified, so that it presents a decided difference from either of the parents, though resembling the one more than the other. In no case, however, are anomalous forms generated bearing no resemblance to either. At the same time they are not produced according to mathematical formulæ and ratios; their differences are mingled in unequal proportions.

3. When the hybrid is impregnated by the original male parent, the result is much the same as in simple hybrids self-fertilised, both in respect of the types produced and the degree of fertility. Various forms are raised from one capsule, and the different individuals do not present the same degree of susceptibility for impregnation. Different capsules, too, offer very different results. When these mules are in

turn self-impregnated, either naturally or artificially, they are commonly more fruitful than they were after the first impregnation. As might be expected, the seedlings approach nearer to the paternal type: when the original simple mules in their second generation and the paternal hybrids of the second degree exhibit a return to the type of the maternal ancestor, such a return is never perfect, but only partial.

This power of muling, properly so called, is confined within very narrow limits, and can hardly be said to exist at all between species of different genera, unless under that name are comprehended some of the spurious creations of inconsiderate botanists. There are, indeed, many cases of species very closely allied to each other which it is either impossible to mule, or so difficult that no one has yet succeeded in effecting it. Mr. Knight never could make the Morello breed with the common Cherry. I have in vain endeavoured to mule the Gooseberry and Currant, and we do not possess any garden production known to have been produced between the Apple and the Pear, or the Blackberry and the Raspberry, any of which might have been expected to intermix. As to mules obtained between plants of distinct genera, we have, no doubt, upon record, some experiments said to have been performed successfully in crossing a Thorn-Apple with Tobacco, the Pea with the Bean, the Cabbage with the Horseradish, and so on; but Mr. Herbert regards these cases, and I think with great reason, as apocryphal, and not to be relied on; the fact being, as he truly states, "that in this country, where the passion for horticulture is great, and the attempts to produce hybrid intermixtures have been very extensive during the last fifteen years, not one truly bigeneric mule has been seen."

He never could cross a *Bomarea* and *Alstrœmeria*, near as they are to each other. But he succeeded, without difficulty, in making *Hermione*, *Ajax*, and *Queltia* breed together, as might have been anticipated from the unbotanical grounds upon which these spurious genera have been carved out of *Narcissus*. The long and carefully conducted experiments of Gærtner ended in the same result; and this author remarks, that supposed cases of muling between *Cucumis* and *Melo*, *Cheiranthus* and *Matthiola*, *Brassica* and *Raphanus*, *Lychnis* and *Saponaria*, *Pisum* and *Vicia*, and some others, all seem to be more or less uncertain in some part of their history.

On the other hand, cross-breeding will take place as readily among plants as among animals, and it is difficult to estimate the alteration which this process has really produced, although unperceived by us, in the amelioration and alteration of long cultivated plants. We cannot reasonably doubt that a process so simple as that of dusting the stigma of one plant with the pollen of another, which must be continually happening in our gardens, either through the agency of insects or the currents in the air, and which, where it takes place between two varieties allied to each other, must necessarily produce a cross,—we cannot suppose, I say, that this occurs in our crowded gardens and orchards at that time only when we perform it artificially.

The operation itself, although so simple, consisting in nothing more than applying the pollen of one plant to the stigma of another, nevertheless requires to be guarded by some precautions. In the first place, it is requisite that the flower whose stigma is to be fertilised should be deprived of its own anthers before they burst, otherwise the stigma will be self-impregnated, and although superfœtation is not impossible, yet it is not likely to occur. Then, again, the application of the stranger pollen should be made at the time when the stigma is covered with its natural mucus; if not, the pollen will not act, either in consequence of the necessary lubrification of itself being withheld, from the stigma being too young, or because the stigma, from age, has lost its power of receiving the action of the pollen. Neither should the stigma be in any way injured after fertilisation has apparently taken place. The art of fertilisation consists in the emission, by the pollen, of certain tubes of microscopical tenuity, which pass down the style, and eventually reach the young seed, with which they come in contact; and, unless this contact takes place, fertilisation misses. Now the transmission of the pollen tubes from the stigma to the ovule, through the solid style, is often very slow, sometimes occupying as much as a month or six weeks, as in the Mistletoe.

Gærtner's experiments lead him to these practical conclusions :—1. The time when impregnation will take place is

comprised within certain limits, varying with the particular species. Very early experiments in hybrid fecundation before the expansion of the blossom seldom succeed, and no impregnation will take place with strange pollen when the stigma has arrived at such a state that its own pollen is not able to fecundate the whole ovary. In any case, however, there is no difference in the hybrid types resulting from the experiment. 2. The stigma, when ready for the reception of the pollen, secretes in every case a greater or less quantity of moisture, which doubtless acts an important part in the process of fecundation. In certain cases it may be thought necessary to apply some fluid to the stigma for the better retention and development of the pollen grains. For this purpose the honey secreted by the flower, or that of some allied species, may be used without any modification of the produce. Oily fluids, such as various purer oils, also have been used with success, though not uniformly. Water, on the contrary, is generally unfavourable, though in some water-plants, in strict analogy with the observations of Spallanzani on the fecundation of the ova of certain aquatic reptiles, it has clearly no injurious if not a beneficial influence. 3. In some cases, especially in those where hybridisation is rare, outward conditions, such as increased temperature, predispose plants for hybrid impregnation, and cultivation in general is favourable to this end, as it is to the production of deviations from a normal condition. Varieties are usually far more disposed to mix than the species from which they are derived, and hence the great difficulty of keeping our most valuable vegetables pure and genuine. Of all genera Calceolaria seems to present the greatest tendency to hybridise; the pure species unite with the utmost facility, and their hybrids are all fertile and disposed to fresh admixture.

He also attaches great importance to what he calls ELECTIVE AFFINITY, or the preference which the stigma has for the pollen of one plant rather than of another. He found that when the stigma is dusted at the same time, or within certain limits, with its own pollen in sufficient quantity, and that of some other species, the latter is wholly inert, and the result is plants

not differing in any respect from the matrix; nor is the effect different if a division or portion of the stigma be dusted with either pollen separately, precaution being taken that there shall be no possibility of admixture. The elective affinity for the natural pollen makes the other completely negative.

After all his experience Gærtner was finally obliged to confess that experiment shows a great, perhaps the greater portion of plants not to be susceptible of hybridisation. Out of seven hundred species submitted to nearly ten thousand distinct sets of experiments only two hundred and fifty true hybrids were raised. Allowing the possibility of repeated experiments proving that union is possible in some cases where it has not yet been obtained, the result is sufficiently striking, showing especially when taken in conjunction with the large number of failures where success has in some cases been obtained, not only that the least portion of the vegetable kingdom is capable of hybrid fecundation, but that as a general rule it is a forcing of nature. It, moreover, seems to be a general rule that the pollen of a species possessing a greater elective affinity neutralises the influence of that of one less closely allied in that respect, as also does that of the matrix the fertility of the pollen of another species.

Those who occupy themselves in attempts at improving the quality of cultivated plants should be aware of this; namely, that the real quality of either the fruit or the flower of a seedling cannot be ascertained when they are first produced, for it is only as plants advance in age that the secretions necessary for the perfect production of either the one or the other are elaborated. Of this fact the first produce of the Black Eagle Cherry-tree afforded a striking example. A part of it was sent, with other Cherries, to the Horticultural Society; and it was then, in the Fruit Committee, pronounced good for nothing. It was so bad, that Mr. Knight, who raised it, would most certainly have taken off the head of the tree, and employed its stem as a stock, but that it had been called the property of one of his children, who sowed the seed which produced it, and who felt very anxious for its preservation. It has now become

one of the richest and finest fruits of its species which we possess.

It may be expected that some mention should here be made of double flowers, and of the manner in which they are to be obtained. But I confess myself unable to discover, either in the writings of physiologists, or in the experience of gardeners, or in the nature of plants themselves, any sufficient clue to an explanation of the causes to which their origin may be ascribed. There are, however, several facts, apparently connected with the subject, which deserve mention.

A double flower, properly so called,* is one in which the natural production of stamens or pistils is exchanged for petals, or in which the number of the latter is augmented without any disturbance of the former; in other words, it is a case of the loss, on the part of a plant, of the power necessary to develope its leaves in the state of sexual organs. But what causes that loss of power we do not know. It can hardly be a want of sufficient food in the soil; for double flowers (the Narcissus, for instance) become single in very poor soil. On the other hand, it can scarcely be excessive vigour, for no one has ever yet obtained a double flower by promoting the health or energy of a species.

On the contrary, the French rely upon a debilitating process to procure double flowers, if we are to credit a writer in the *Revue Horticole*, who expresses himself thus:—Every gardener who sows seed, wishes to obtain plants with double flowers, so as to obtain blossoms which produce the greatest effect. Every double plant is a monstrous vegetable. To produce this anomaly, we must attack the principle of its creation, that is to say, the seed. This being granted, let us examine in what way these seeds ought to be treated. If, after having gathered the seeds of Malcolmia annua, or Ten-weeks Stock, we sow them immediately afterwards, the greatest number of the seedlings will produce single flowers, whilst, on the contrary, if we preserve these same seeds for three or four years, and then sow them, we shall find double flowers upon nearly all the plants. To explain this phenomenon, we say that

* What is called a Double Dahlia is misnamed; and so are all so-called double composite flowers. The appearance of doubling is caused in these plants by a mere alteration of the florets of their disk into the form of florets of the ray, a very different thing from double flowers.

in keeping a seed for several years, we fatigue it and weaken it. Then, when we place it in a suitable soil, we change its natural state, and from a wild plant make it a cultivated one. What proves our position is, that plants, in their wild state, shedding their seeds naturally, and sowing them as soon as they fall to the ground, yet in a long succession of time scarcely ever produce plants with double flowers. We think, then, after what we have said, that whenever a gardener wishes to obtain double flowers, he ought not to sow the seeds till after having kept them for as long a time as possible.—This practice ought to be observed with all plants that we wish should produce double flowers, for all varieties of the Brompton Stocks, Pinks, &c.

When plants are excessively stimulated by unusually warm damp weather at the period of flowering, their flowers in such cases sometimes become monstrous: but the effect of this is to lengthen their axis of growth, and to form true leaves instead of floral organs, just the reverse of what occurs in a truly double flower; the varieties of Rosa gallica often exhibit this kind of change. In damp cloudy summers, some flowers assume the appearance of being double, by the change of their sexual organs into small green leaves, as occurred very generally to Potentilla nepalensis in the summer of 1839, a representation of which is given at page 90; but there was, at the same time, scarcely a trace of any tendency, on the part of those leaves, to assume the colour or texture of petals.

There is, evidently, a greater tendency in some flowers to become double than in others, and especially in those having great numbers of stamens or pistils. All our favourite double flowers, Hepaticas, Pæonies, Camellias, Anemones, Roses, Cherries, Plums, Ranunculuses, belong to this class; and, in proportion as the natural number of stamens diminishes, so do both the disposition to become double, and the beauty of the flowers when altered. The Pink and Carnation with ten stamens are the handsomest race next to those just mentioned; while the Hyacinth, the Tulip, the Stock, and the Wallflower with six stamens, and the Auricula and Polyanthus with five, form altogether an inferior race, if symmetry of form, and regularity of arrangement in the parts of the flower, are regarded as beauties of the highest order. If the mere circumstance of a plant having but a small number of stamens be a

bar to its beauty when made double, how much greater an obstacle to it must be the natural production of unsymmetrical flowers. This occurs in the Snapdragon, which, with a five-lobed corolla, has but four stamens; and the consequence is, that, when it becomes double, the flower is a confused crowd of crumpled petals issuing from the original corolla.

Attempts have been made to produce double flowers by artificial processes, but I never heard of the smallest success attending such cases, unless the tendency to their production had already manifested itself naturally; as in the Stock, which will frequently become single from having been double, in which case its original double character may be recovered. A mode of effecting this has been described by Mr. James Munro. (*Gard. Mag.*, xiv. 121.) Having a number of Single Scarlet Ten-week Stocks, he deprived them of all their flowers as soon as he found that five or six seed-vessels were formed upon each spike, by which means he compelled all the nutritive matter that would have been expended upon the whole flower-spike and its numerous seed-vessels to be concentrated in the small number which he left; and the result, he says, was, that from the seed thus saved he had more than 400 Double Stocks in one small bed.

Gærtner asserts that in the production of double blossoms, it is a matter of indifference whether the pollen be taken from a double or single variety, provided the flower of the mother is double.

There can be little doubt that, if any original change to a double flower can be effected by art, it will be more likely to occur with respect to those species which have an indefinite number of stamens, where the tendency to this monstrosity already exists. It is not many years since the Chryseis (Eschscholtzia) californica, a polyandrous plant, was introduced to our gardens: and I, at one time, made some attempts to render it double, conceiving it a good subject for experiment on that account, but I had no success; it, however, accidentally became semi-double in Mrs. Marryat's garden, at Wimbledon; and we still see semi-double plants in our gardens.

It appears from evidence, the truth of which can scarcely be questioned, that in some cases the most highly improved races of cultivated plants suddenly revert to, or far towards, their wild state when raised from seed.

M. Chevreuil, in an ingenious essay on "Species," makes the following statement:—"In North America, neither Pear-trees, nor Apple-trees, nor Peach-trees exist in a wild state, belonging to the species of our own continent. The Europeans, in settling there about three centuries since, carried thither the seeds of these trees; but instead of reproducing our cultivated variety, *they yielded* at least in Virginia, *in the first generation, trees producing nothing but wild fruit, too austere to be eaten by people accustomed to our cultivated fruits.* The seeds of the American fruits of this first generation, produced trees whose fruit was a little less bad than those of the preceding generation; and finally, from generation to generation, there was a perceptible improvement, but still of such a nature that the fruits last produced are still inferior to our own; and, what is remarkable, those which have improved the most from seed differ from the fruits of Europe in taste and perfume. These facts, which M. Poiteau collected in Virginia five-and-forty years ago, prove the modifications produced by a succession of generations of plants, the issue of a single seed, and at the same time justify my definition of a species. And if it is said that the seeds of the first fruit-trees sent to Virginia could not have belonged to varieties possessing qualities of the same excellence as the varieties now cultivated, nevertheless the fact would remain that *fruits gathered in Virginia were absolutely different from those which their ancestors produced at the same time in Europe.*"

Thatcher, in his *American Orchardist*, confirms this. He says, that "a hundred seeds of the Golden Pippin will produce large-leaved Apple-trees (the Golden Pippin itself has a small leaf), bearing fruit of a considerable size; but the tastes and colours of each will be different, and none will be the same in kind with the Pippin. Some will be sweet, some bitter, some sour, some mawkish, some aromatic; some yellow, others green, red, or streaked."

From this it would seem that we are to infer that the climate of N. America is so unfavourable to the Apple and Pear, that when these trees were first raised there from seeds, they immediately lost their domesticated qualities, and went back to their original wild nature. If the facts are really as stated, we must infer that the seeds had been accidentally crossed in Europe with wild races; which is quite possible, and this becomes the more probable when it is recollected that in the remote times, three centuries ago, to which the American authorities refer, wild Pears and Apples must have been much more abundant than now, and their pollen was far more likely to contaminate domesticated plants.

We can scarcely doubt indeed that something of this kind occurs even now. Mr. Thompson states as the result of his own great experience that "Seedlings from the same tree not only differ widely from each other, but even those from pips, taken from the same Apple, produce fruit possessing qualities entirely different. For example, the excellence of the Ribston Pippin need only be mentioned; but the "Sister Ribston Pippin" was a white, semi-transparent, sour-fleshed Apple, or rather a large Crab. It therefore appears that the same fruit may contain the germs of good and bad, both protected by the same pulp and nourished by the same juice. Whether the fruit of the parent tree of these possessed intrinsic merit has not been ascertained; but this we know, that many seeds from the Ribston Pippin have been raised, yet none of its progeny are found to inherit its peculiar flavour and excellence. The same remark applies to the old Nonpareil." From these facts he infers that there is a strong tendency in plants from *seeds of cultivated fruit-trees of high quality to revert immediately to the state of wildings.*

Undoubtedly this may be so, but we incline to refer such sudden changes much more to accidental cross-breeding. We do not now receive from our colonies complaints of the bad quality of the seedlings raised from highly domesticated European fruits, and yet for at least twenty years the Horticultural Society has annually sent considerable quantities of Peach, Nectarine, Plum, Cherry, and Apricot stones, pips of

Apples and Pears, and seeds of Strawberries, Raspberries, Gooseberries, and Currants, always selected from the finest varieties cultivated in England. It is, moreover, entirely at variance with the experience of the great Belgian fruit growers. (See De Jonghe on raising Pears from seed in the *Gardeners' Chronicle*, 1855, p. 21.)

CHAPTER XIX.

OF RESTING.

A GARDENER is said to rest a plant when he exposes it to a condition in which it cannot grow, aud which is analogous to its winter state. For many parts of gardening, especially what relates to forcing, and the management of exotic plants, this is a subject of the first importance.

If we look over the different climates of the world, we shall find that in each there are a season of growth, and a season in which vegetation is more or less suspended; and that these periodically alternate, with the same regularity as our summer and winter. I do not know that there is in nature any exception to this rule: for even in the Tierra templada of Mexico, where it is said that, at the height of 4000 to 5000 feet, there constantly reigns the genial climate of spring, which does not vary more than 8° or 9°, intense heat and excessive cold being alike unknown, and the mean temperature varying from 68° to 70°, we cannot suppose that, even in that favoured region, a season of repose is wanting; for it is difficult to conceive how plants can exist, any more than animals, in a state of incessant excitement. Indeed, it is pretty evident that these countries have a period when vegetation ceases; for Xalapa belongs to the Tierra templada, and we know that the Ipomœa purga, an inhabitant of its woods, dies down annually like our own Convolvuli. We also know that Jonquils, Hyacinths, and Tulips when grown in the Bahamas, where they are unable to take the rest which is natural to them, refuse to flower.

But, although all plants have naturally a season of repose, their winter is not in all cases cold. In the topics it is marked

by coolness and dryness, while the summer is rainy and very hot; and in extra-tropical countries the two seasons vary in their character, according to latitude and local circumstances.

In some parts of Persia, Armenia, and Mesopotamia, the summer heats are excessive, while the winters are rendered cold by the proximity of mountains. Bagdad is described as having a cold winter, because of the proximity of the mountains of Koordistan; yet its heats are intense: in August, 1819, the thermometer stood at 120° in the coldest parts of the house, and at 108° at midnight in the open air. This was preceded by heavy rains, which raised the Euphrates $7\frac{1}{2}$ feet above the ordinary level: the whole country was like a vapour bath, and multitudes of persons dropped down dead: twenty-two in three days in a single caravan. In the northern provinces of Mexico the winters are of German rigour, while the summers are those of Naples and Sicily; the Tierra fria of its southern provinces has however a very different climate, the mean heat of the summer being 76°, and the winters so mild that the thermometer only occasionally falls below 32°.

At the Cape of Good Hope there are districts in which the period of wet is long and very severe; and many of the favourite flowers of our gardens are produced by those districts. The Karroos are plains of great extent, destitute of running water, with a soil of clay and sand, coloured like yellow ochre by the presence of iron, and lying on the solid rock. During the dry season the rays of the sun reduce the soil nearly to the hardness of brick: Fig-Marigolds, Stapelias, and other fleshy plants, alone remain green; nevertheless, the bulbs and tubers of Irids and other plants are able to survive beneath the sun-scorched crust, which appears indeed to be necessary to their nature. But in the wet season these bulbs are gradually reached by the rain; they swell beneath the earth; and at last develope themselves so simultaneously that the arid plains become at once the seat of a charming verdure. Presently afterwards, myriads of the gay flowers of Irids and Mesembryanthemums display their brilliant colours: but in a few weeks the verdure fades, the flowers disappear, hard dry stalks alone remain; the hot sun of August, when in those latitudes the

days begin to lengthen, completes the destruction of the few stragglers that are left, the Karroo again sinks into aridity and desolation, and the desert reappears. What succulents survive are covered with a grey crust, and derive their nourishment only from the air. In other parts of the Cape of Good Hope the mean range of the thermometer in winter is 48° to 93°, with cold rain, while that of the summer is from 55° to 96°, with dry days and damp nights.

In the Canaries we have the season of growth from November to March, when rains fall like those of Europe, and the mean temperature is 66°; the period of rest is April to October, when it never rains, and the mean temperature is 73°.

In Brazil the seasons are thus described by Mr. Caldcleugh:—"The summer begins about the months of October or November, and lasts until March or April. This is the wet season; but the rains by no means descend from morning till night, as in some other tropical countries, but commence generally every afternoon about four or five o'clock with a thunderstorm. The heaviness of the rain can only be conceived by those who have been in these latitudes. This fall naturally arrests the sea breeze, and the succeeding night is dark and cloudy. Formerly these diurnal rains came on with such regularity that it was usual, in forming parties of pleasure, to arrange whether they should take place before or after the storm. During this period of the year there is seldom, if ever, a deposition of dew. From April until September very little rain falls; vegetation almost stops, and, to the eye of every one who has not just arrived from Europe, a wintry appearance is discernible. The land and sea breezes do not succeed each other with the same regularity, and are, besides, more frequently disturbed by violent gusts from the S. W., imagined to be the tails of those destructive winds, the Pamperos of the River Plate. The nights are beautifully clear; Venus casts a shadow, and the southern constellations are seen in all their beauty. The dews, as might be expected, are at this season very copious." (*Brande's Journal*, No. 27. p. 41.)

The periods of rest and activity in the vegetable world are, however, not always evident. The vegetation of the primitive forests of Brazil,

writes Aug. de St. Hilaire, is in a state of constant activity. The winter is only distinguished from the summer by a changed green of the leaves, and if some trees lose their leaves it is only to be immediately replaced with new ones. In some districts, however, the trees become leafless every year. This happens when the rains, which endure for six months, suddenly cease, which takes place in February, and the heat increases gradually till June. In this latter month the trees are almost leafless, but in August again, before the rain commences, the buds have again expanded, and the trees are covered with leaves. The cause of this fall of the leaf is no doubt owing to the dryness of the soil, but it can only occur in some exposed districts of the primitive forests, as in most cases the trees are found on the borders of great rivers and on naturally damp soils, where the earth into which they strike their roots is never dry.—*Treviranus.*

In other parts of the tropics the seasons of growth and rest are equally marked. In Ava, during the rainy season, which lasts from May to October, the mean temperature varies from 78° to 91.5°; while, in the dry season, from November to April, it falls to from 63° to 80°. At Calcutta, in the growing season, from April to October, fifty-eight inches of rain commonly fall, with a mean temperature of 79° to 86°; while during the season of rest, from November to March, there is not perhaps an inch of rain, and the thermometer sinks to from 66° to 80°. At this time vegetation is said, in such countries, to "labour under a deadly languor; but one night's rain converts an arid plain into a verdant meadow."

In most of the West India Islands situated under the tropic of Cancer, there is said not to be much difference in the climate, so that accurate observations made on any one of them may be applied with little variation to them all. Malte Brun gives the following sketch of their seasons. "The spring begins about the month of May; the savannas then change their russet hue, and the trees are adorned with a verdant foliage. The periodical rains from the south may at this time be expected; they fall generally about noon, and occasion a rapid and luxuriant vegetation. The thermometer varies considerably; it falls sometimes six or eight degrees after the diurnal rains, but its medium height may be stated at 78° Fahrenheit. After these showers have continued for a short period, the tropical summer appears in all its splendour.

Clouds are seldom seen in the sky; the heat of the sun is only rendered supportable by the sea breeze, which blows regularly from the south-east during the greater part of the day. The nights are calm and serene, the moon shines more brightly than in Europe, and emits a light that enables man to read the smallest print; its absence is in some degree compensated by the planets, and above all by the luminous effulgence of the galaxy. From the middle of August to the end of September, the thermometer rises frequently above 90°, the refreshing sea breeze is then interrupted, and frequent calms announce the approach of the great periodical rains. Fiery clouds are seen in the atmosphere, and the mountains appear less distant to the spectator than at other seasons of the year. The rain falls in torrents about the beginning of October, the rivers overflow their banks, and a great portion of the low grounds is submerged. The rain that fell in Barbadoes in the year 1754 is said to have exceeded eighty-seven inches. The moisture of the atmosphere is so great, that iron and other metals easily oxidated are covered with rust. This humidity continues under a burning sun; the inhabitants (say some writers) live in a vapour bath." (*Malte Brun's Geography*, vol. v. p. 569, Eng. ed.)

It is evident, from what has been said, that the natural resting of plants from growth is a most important phenomenon, of universal occurrence, and that it takes place equally in the hottest and the coldest regions. It is, therefore, a condition necessary to the well-being of a plant, not to be overlooked under any circumstances whatever, and there cannot be any really good gardening where this is not attended to in the management of plants under glass. Rest is effected in one of two ways, either by a very considerable lowering of temperature, or by a degree of dryness under which vegetation cannot be sustained.

The way in which the physical powers of vegetation are affected by this has been already explained, and in practice it is found a point of the utmost consequence. The early fruit-gardener draws his Vines out of the vinery, and takes the sashes from his Peach and other forcing-houses, when the

artificial season of growth is over, in order to prepare them for the duty of a succeeding season; although this operation is performed in summer, its effect is to expose them to dryness, which arrests their growth, and favours the deposit in their wood of the matter required for the produce of a succeeding year.

The effects of a very dry atmosphere are necessarily an inspissated state of the sap of the plant, and this in all cases leads to the formation of blossom-buds and of fruit. It thus operated upon some Pine-apple plants in Mr. Knight's garden, to such an extent as to cause even the suckers from their roots to rise from the soil with an embryo Pine-apple upon the head of each, and every plant to show fruit, in a very short time, whatever were its state and age. Very low temperature, under the influence of much light, by retarding and diminishing the expenditure of sap in the growth of plants, comparatively with its creation, produces nearly similar effects, and causes an early appearance of fruit.

The operations of forcing are essentially influenced by these facts; and, by a skilful alteration of the periods of rest, we are enabled to break in upon the natural habits of plants, and to invert them so completely that the flowers and fruits of summer are obtained to load our tables even in winter. Of this, the following instance, taken from a paper by Mr. Knight in the *Horticultural Transactions* (vi. 232), is a sufficient illustration.

"A Verdelho Vine, growing in a pot, was placed in the stove early in the spring of 1823, where its wood became perfectly mature in August. It was then taken from the stove and placed under a north wall, where it remained till the end of November, when it was replaced in the stove, and it ripened its fruit early in the following spring. In May it was again transferred to a north wall, where it remained in a quiescent state till the end of August. It then vegetated strongly, and showed abundant blossom, which, upon being transferred to the stove, set very freely, and the fruit, having been subjected to the influence of very high temperature, ripened early in the month of February."

The Strawberries of February and March are in like manner

ocured by exposing the plants to such an amount of dryness d heat as can be obtained by presenting them unwatered, in ts, to the sun at an early period of summer, so as to cause a fficient accumulation of excitability by the end of autumn, stead of the month of May.

It must be manifest that the operations of the flower-rdener should be regulated by the same principles, although may be confessed that they are often little considered; a cumstance the more strange, from the indispensable neces-y of resting fruit-trees being universally known. It is to e giving their plants the proper kind of rest that some garde-rs owe the magnificent blossoming of their Chinese Azaleas, cti, Camellias, and other forced flowers, much more than to y peculiarity in the compost they employ, which is often a int of subordinate interest, although often regarded as of the st importance.

If little progress has been made in altering the time of wering of particular races, so as to invert their seasons, this certainly far from being beyond attainment; and there is no re reason why a Chinese Chrysanthemum should not be mpelled to flower at midsummer instead of November, or a hlia at Christmas, than that Vines and Strawberries should en fruit in February. The great difficulty to contend ainst in obtaining winter flowers is want of light and free cess to air; but, by the employment of slender iron sash-rs and large glass, a sufficient amount of light may be tained in England even at that season of the year; it is the free admission of warm moist air that gardeners are ficient (see pages 213, &c.).

It is well known that plants from the northern half of the world, when they have become naturalised in the south, have changed almost entirely the time of their vegetating, blooming, and fruit-bearing, so as entirely to accord with the habits of the indigenous plants of the country. Thus we find that at the Cape of Good Hope, Oaks, Alders, the Almond, Peach, and Apricot, are in full bloom in August.—*Treviranus.*

But it is not merely the periodical rest of winter and summer at plants require; they have also their diurnal repose: night

and its accompanying refreshment are as necessary to them as to animals. In all nature the temperature of night falls below that of day, and thus one cause of vital excitement is diminished; perspiration is stopped, and the plant parts with few of its aqueous particles, although it continues to imbibe them by all its green surface as well as by its roots; the processes of assimilation are suspended; no digestion of food and conversion of it into organized matter takes place; and, instead of decomposing carbonic acid by the extrication of oxygen, they part with carbonic acid, and rob the air of its oxygen; thus deteriorating the air at night, although not to the same amount as they purify it during the day. It is, therefore, most important, that the night temperature of glass houses should be lower than that of the day. We are told that in Jamaica and other islands of the West Indies, the air upon the mountains becomes, soon after sunset, chilled and condensed, and, in consequence of its superior gravity, descends and displaces the warm air of the valleys; yet the sugar-canes are so far from being injured by this decrease of temperature, that the sugars of Jamaica take a higher price in the market than those of the less elevated islands, of which the temperature of the day and night is subject to much less alteration. At Fattehpúr, in the East Indies, the difference in temperature between night and day amounts to from 38° to 45°; in April the greatest heat by day is 110°, that of night is only 65°; in January the thermometer falls to 38° at night, while the day is 76°; and there are 40 degrees of difference between the day and night in May, one of the hottest months, when the thermometer ranges as high as 115°. At Calcutta, in May, the thermometer averages 93° in the day, and 79° at sunrise; while in January the temperatures are 77° and 56° respectively for those two periods.

But it is not merely in the tropics that this great diminution of temperature at night takes place; it is universally the case in all climates whence our fruit-trees have been derived. When we consider how clear the sky is in the lands of the East, it is impossible that there should not be a great amount of nocturnal radiation, the effect of which will necessarily be to cool down the air to a very considerable extent, especially in the spring. If we look to the registers of temperature

kept in such countries, that which was before a matter of inference becomes established by direct evidence. Take Malta as an example: in the month of January, according to Dr. Davy, the thermometer reaches 60° in the day, but falls to 42° at night; and even in July, the difference between the day and night amounts to 16°. In the Ionian Islands, Zante, Corfu, Cephalonia, fine Grape countries, the difference is not less considerable. Nevertheless, many gardeners, when they begin forcing early Grapes, quite neglect this important fact. With some it is a maxim to keep the thermometer above 60° at night. But what does nature do where the Vine thrives best? In Zante, whence come the Currants, or Corinth Grapes of the shops, the Vine pushes in March; and it is a common saying there, "that after the 10th March (Old Style), not even a dog without a tail should be allowed to enter a Vineyard," (*Davy's Ionian Islands*, ii. 345) because of the risk of his breaking off the young and tender shoots. Now the average temperature of Corfu, at 8 A.M., in the month of March, we learn from the same authority, is only 51°; and of course it must have been some degrees lower during the night; in April it is not more than 57°; and it does not reach 61° till May, when, since the Grapes are ripe in August, the berries must be set. There can be no doubt, then, that 48° is quite high enough at night for Grapes in the first month of their growth, and 54° in the second.

But there are other illustrations if we inquire into the natural history of the Grape Vine. Nowhere is the climate more sultry than in Affghanistan. We are told that General Pollock's troops at Jellalabad were forced to dig holes in the ground to hide themselves from the heat. The condition of Cabul must be much the same. At Candahar, we are informed by Mr. Atkinson that, in May, the heat of the tents was generally 110°; and at midday, in the sun, 140°. In no part of the world are the Grapes more delicious than in Candahar and Cabul. On the 30th June, this traveller saw donkeys laden with panniers of fine purple Grapes; and at the same time, the paper on which he was writing curled up and became as crisp as if it was before a blazing fire. When he reached Cabul, in August, he found the bazaar filled with delicious Grapes in astonishing profusion. But what sort of nights had the troops in the spring of the year, when the Vines were growing and flowering, and preparing themselves to bear fruit? On the 7th March, near Shikapore, two hundred miles *south* of Candahar, and above five hundred *south* of Cabul, in the Desert, we are told that the march took place in "a brilliant starlight night; frost seemed to be in the air, it was so cool and bracing; after midnight, the servants made up a blazing fire, for the north wind was blowing bitter cold, and the traveller was glad of hot brandy and water." Nevertheless, the day before, Mr. Atkinson had been *grilling* at Shikapore, and the march was over level plains, and not among the mountains. Two days after-

wards the weather is described as being oppressively hot at mid-day. Then on the 19th March there was a hailstorm at night, and the air was "cold and bracing;" and so on. Here, then, in a country totally different from the islands of the Mediterranean, where the Grapes are famous for their excellence, we have violent variations in temperature between day and night in the month of March, when the Vines are shooting: the air is cold and bracing by night, the sun is grilling by day.

It is probable, however, that no one has been prepared for such a fall of temperature by night as is recorded in Sir Thomas Mitchell's late Journal into the interior of tropical Australia. The facts revealed in this interesting work have been fully extracted and made the subject of comment in one of the numbers of the *Journal of the Horticultural Society of London*. For details the reader is referred to that work. The following is the author's summary of the facts.

"In the end of April (our October), in latitude 82° S., within 4½° of the tropic, at an insignificant elevation, the thermometer stood at 26° at sunrise, and was as low as 43° at 9 P.M.; nevertheless, the country produced wild Indigo, Mimosas, Casuarinas, arborescent Myrtleblooms, and Loranths. A degree nearer the tropic in May (our November), the thermometer at sunrise marked 20°, 19°, 18°, 17°, 16°, 12°, and on two separate days, even 11°! On the 22d of May the *river was frozen*, and yet herbage was luxuriant, and the country produced Mimosas, Eucalypti, Acacias, the tropical Bottle-tree (Delabechea), a Calandrinia, and even a Loranth. On the 23rd of May the thermometer at sunrise marking 12°, Acacia conferta was coming into flower; and Eucalypti, with the usual Australian vegetation, were abundant. On the 30th of May, at the elevation of 1118 feet, the almost tropical Delabechea was found growing with the temperature at sunrise 22° and at 9 P.M. 31°, so that it must have been exposed to a night's frost gradually increasing through 12°. And this was evidently the rule during the months of May, June, and July (our November, December, and January); in latitude 26° S. among Tristanias, Phebaliums, Zamias, Hoveas, Myoporums, and Acacias, the evening temperature was observed to be 29°, 22°, 37°, 29°, 25°, falling during the night to 26°, 21°, 12°, 14°, 20°; in latitude 25° S. the tents were frozen into boards at the elevation of 1421 feet, the thermometer, July 5, sunk during the night from 38° to 16°, and there grew Cryptandras, Acacias, Bursarias, Boronias, Stenochiles, and the like. Cymbidium canaliculatum, the only Orchidaceous epiphyte observed, was in flower under a night temperature of 33° and 34°; that by day not exceeding 86°. These facts throw quite a new light upon the nature of Australian vegetation. It may be supposed that so low a temperature must have been accompanied by extreme dryness, and such appears to have been usually the case. Nevertheless, it cannot have been always so, for although Sir Thomas

Mitchell made no hygrometrical observations in June and July, and only four in May, yet there is other evidence to show that the dryness cannot always have been remarkable. In May the hygrometer indicated ·764, ·703, ·934, or nearly saturation, and ·596; yet the sunrise temperature was on those occasions 25°, 28°, 30°, and 34°. On the 22nd of May the Grass was white with hoar frost, and the thermometer was at sunrise 20° under canvas and 12° in the open air. On the 5th of July, when it rained all day and the tents were 'frozen into boards,' the thermometer sank during the night from 38° to 16°. No doubt this power of resisting cold is connected with the very high temperature to which Australian vegetation is exposed at certain seasons, and this is horticulturally a most important consideration. We find that in latitude 32° S. in January (our July) the thermometer stood eight days successively above 100°, and even reached 115° at noon; that it was even as high as 112° at 4 P.M.; that in the latter part of February one degree nearer the line it was twice 105° and once 110°; that in March, one degree further northward, it frequently exceeded 100°, and there was not much fall in this excessive temperature up to the end of April. This will be more evident from the following

Table of Noon-day Temperatures.

Latitude.						Max.	Min.
29° S.	Nov., Dec. .	Average of	3	Observ.,	102°	103°	62°
32 S.	Jan., Feb. .	,,	18	,,	97½	115	73
31 S.	Feb., March	,,	17	,,	90	110	80
30 S.	March . .	,,	20	,,	95	105	84

"Even such heats as these do not, however, destroy the power of vegetation, for we find in the midst of them all sorts of trees in blossom; a few bulbs, and even here and there (in damp places, no doubt) such soft herbs as Goodenias, Trichiniums, Helichrysum, Didiscus, Teucrium, Justicia, herbaceous Jasmines, Tobacco, and Amaranths. During these heats the night temperature seldom remains high. Sometimes, indeed, the thermometer was observed as much as 88°, and once even 97° at sunrise, the average noon-heat of the month being 97½°, but generally the temperature is lower. Thus:

				Temperature occasionally at Sunrise.				
Nov. and Dec.,	averaging	102°	at noon,	62°,	58°,	61°.		
Jan. and Feb.	,,	97½	,,	61	60	59	47°,	&c.
Feb. and March	,,	90	,,	61	59	54	48	&c.
March . . .	,,	95	,,	68	55	51	47	&c."

These facts seem to demonstrate that it is the purpose of nature to reduce the force which operates upon the excitability

of vegetation at that period of the twenty-four hours, when, from other causes, the powers of digestion and assimilation are suspended. As far as is at present known, that power is heat; and therefore we must suppose that, to maintain at night in our hot-houses a temperature at all equal to that of the day, is a practice to be condemned. Plants will no doubt lengthen very fast at night in a damp heat, but what is at this time produced seems to be a mere extension of the tissue formed during the day, and not the addition of any new part; the spaces between the leaves are increased, and the plant becomes what is technically and very correctly called "drawn"; for, as has been justly observed, "the same quantity only of material is extended to a greater length, as in the elongation of a wire."

Some observations made in the garden of the Horticultural Society a few years since place this in a striking light. Certain plants were placed for several weeks in a stove, with a high night temperature—supposed to average 69°: the following were the rates of growth in inches:—

	Night.	Day.
Fig	9.60	9.92
Willow	19.08	21.55
Passionflower	36.20	35.85
Vine	34.15	34.45
	99.03	101.77

That is to say, they grew as fast by night as by day, for the apparent difference is obviously unimportant. But when these and other plants were grown in the open air, exposed to the low night temperature of England, the result was wholly different, as will be seen by the following table:—

	Night.	Day.
Fig	1.63	6.80
Willow	3.77	9.94
Hop	42.02	100.53
Vine	2.34	4.20
Scarlet Runner	23.11	97.72
Jerusalem Artichoke	8.23	22.25
Gourd	21.23	48.05
	102.33	289.49

The last experiment being carried still further, by observations continued during a part of another month, the result remained the same, the total growth by night being 119.07, and by day 337.16. Thus we see that plants exposed to natural circumstances only made one inch of growth by night while they made three by day; but that, on the contrary, under bad artificial treatment, they grew *equally day and night.* The inevitable consequence of this inversion of natural growth is immature or unripe wood, with imperfect ill-constructed buds, and a feeble constitution, incapable of bearing the shock of great falls in temperature. More especially, water accumulates in the system, and is never decomposed or removed by perspiration, in the requisite degree. In short, plants growing fast by night can neither ripen their wood nor form their inner structure well. And therefore they are incapable of developing their natural beauty, or of resisting those extremes of temperature which are natural to them.

This seems to explain why our greenhouse plants would perish under the night temperature to which they are exposed in New Holland. They are in the condition of a Peach-tree kept growing fast in a forcing-house, and turned out for the winter without having ripened its wood: if that is done it dies, and yet the Peach-tree, when properly ripened, is capable of resisting much severer winters than England ever knows. An Oak-tree, treated in the same way, would be as tender.

If, however, the English gardener cannot command an Italian or Australian sun, if he cannot expose his plants for days together to a temperature of 100°—115°, and if, therefore, he cannot harden their tissues, and strengthen their constitution so as to enable them to bear the rudeness of their native land, there are other things which he can do. He can keep down their growth at night, he can maintain among them continual currents of air, and having done this skilfully he will have done all that the circumstances of his position render possible.

It will be apparent from these remarks that gardeners are not recommended to freeze their greenhouse and stove plants, because they are frozen habitually in Australia, and occasionally

in Bengal. He cannot possibly do artificially all that is requisite to enable plants to bear such extremes. But that is no reason why he should not approach the operations of Nature as near as the different circumstances will permit, and why he should not so treat his plants as will enable them to bear a degree of cold to which, when mismanaged, he dare not expose them.

That greenhouses ought not to be heated at night more than is sufficient to exclude frost is certain; that, if properly prepared, plants will bear frost is also indisputable, as indeed is proved by the Camellias, Chinese Azaleas, and similar plants which are kept in cold frames through our hardest winters, and where they thrive far better than in greenhouses.

With stove plants it is different: experiments are needed to determine how much cold they will bear at night. There seems to be no doubt that the colder they can be safely kept the better for the plants. We must not forget that Mr. Barnes fruited admirable Pines in the open air, and that where Cymbidium canaliculatum was found by Sir Thomas Mitchell in full flower, the thermometer fell at night to 33° and 34°. It is probable that a minimum night temperature of 40° or 45° will be found sufficient, as Mr. Beaton long since asserted; especially if the soil can be maintained at 60° or 65°.

Mr Henry Bailey, of Nuneham, a most experienced and intelligent practical gardener, has expressed his fear that a low night temperature will not agree with stove plants, and mentions the following experiment tried by himself. His employer having no stove for plants, he has been in the habit of growing a few kinds every year by removing them from one structure to another, as dictated by convenience. One year some fine specimens were thus obtained of Euphorbia jacquiniflora and punicea, Stephanotis floribunda, Clerodendron splendens and others, which having completed their growth by the end of September, were removed into a late Vinery varying in nocturnal temperature from 35° to 43°. In this place they received scarcely any water; their treatment in all other respects being subservient to the preservation of the Grapes, for which slight fires were lighted every morning, and ventilation given on all possible occasions to dispel damp. All went on apparently well, till a house being about to be started for forcing flowers, the plants were removed into it, with a night heat of from 45° to 50°, allowing it to rise 10° more with sun heat. The Clerodendron splendens, which maintained

the most luxuriant verdure of leaf up to this time, then sickened and died, every leaf falling off. Euphorbia jacquiniflora lost all its leaves, but the Stephanotis was not materially injured.

On the other hand, Mr. Spencer, another of our great gardeners, has had to manage a house at Bowood, which, though generally called a stove, and filled with stove plants, is never kept during the winter months at a higher temperature than from 40° to 50° by fire heat. The plants are principally used for decorating rooms, and for this purpose late flowering plants are mostly cultivated. The roof is partially covered with creeping stove plants, including Combretums, Bignonias, Passifloras, Stephanotis, &c. The effect of this low temperature on these and similar plants is to produce not only an entire cessation from growth in winter, but in some cases they become partly deciduous, and he found that they bore this low degree of heat not only without injury, but when the warm days of spring returned they broke with unusual strength and vigour, enjoying as they do, in fact, almost a natural climate. It is generally thought Bignonia venusta will not bloom freely except it grows in bottom-heat. That plant grows in a border inside this house, without having any bottom-heat beyond what the house affords, which, during the autumn and winter, is necessarily very low; and yet the plant is every season covered with bloom for two or three months. Stephanotis blooms equally well in July, and the Combretums and Passifloras nearly throughout the year. Echites splendens blooms equally well in the summer, and he finds the flowers of a much higher colour than those from plants grown in a warmer house; in the winter Echites becomes a deciduous tree.

The same result was obtained at Drayton Manor, where, in a Vinery, Pergularia odoratissima, Echites splendens, Stephanotis floribunda, Bignonia Chamberlayniæ, Combretum purpureum, and Clerodendron volubile were planted in the year 1847 against the back wall, and where they grew in the greatest vigour. Mr. Milne's account of their treatment is this:—"When the stove climbers were planted on the back wall of the Vinery, it was with the understanding that they should receive the same treatment as an early Vinery requires, and live or die. At the same time what could be done was done for them, in order to preserve them through the winter; water was withheld from them after September, in order to induce rest before the dead of the year. No particular attention was paid to the thermometer in the house, few fires were used in the winter, and the temperature of the house was frequently as low, in the mornings of frosty nights, as 35°, and on one occasion 32°, when the earth in watered pots in this house was frozen; no fire was made to thaw, but they took their chance. The house was fully opened on all mild days, and partially so every day during the winter. The temperature of the earth about their roots was not always measured, but it is known to have been 58°, and in the absence

of all moisture it may have indicated not less than 50° in January. The most difficult period to deal with those climbers was found to be the time of starting. In a short time after the application of heat they began to exhibit some signs of debility, but a low night temperature (40°), and water withheld still, overcame this small difficulty. Similar results were obtained by Mr. D. Beaton, and others.

Upon the right understanding of these great facts depend all the details of forcing, which is never successful unless the habits of a plant in a wild state are carefully followed. By way of illustration, the case of the Strawberry may be taken as a very common and well understood plant, from which, however, unskilful gardeners obtain no crop when forced, although, as they say, they give it plenty of heat, shut it up close at night, and expect to gather ripe fruit from it in six weeks. They evidently do not consider how it is that the Strawberry is made to bear fruit *naturally*. The cold of winter does not suddenly change to the heat of the dog-days. Warm dew does not incessantly bathe the rising herbage. The nights of spring are not more oppressive than the days. In short the climate in which the Strawberry naturally delights is not in the smallest degree like that which is provided for it. On the contrary, where the Strawberry dwells the temperature rises very slowly, and at about the same rate as light increases; if one day is warm another is cold, and the nights are always so; the air, too, is dry more often than damp—as will be evident if we bear in mind how ceaselessly the east wind breathes upon the land of Strawberries. Three long months of steady growth are required to produce the Strawberry under these favourable circumstances. It is therefore folly to imagine that in six weeks the same end is to be accomplished by unnatural means. We may assist Nature, we cannot compel her. What is true of the Strawberry is equally so of all other forced productions, whether fruits or flowers.

Knight pointed out as one of the ill effects of high temperature during the night that it exhausts the excitability of a tree much more rapidly than it promotes its growth, or accelerates the maturity of its fruit, which is, in consequence, ill supplied with nutriment at the period of its ripening, when most nutriment is probably wanted. The Muscat of Alexandria

and other late Grapes are, owing as he thinks to this cause, often seen to wither upon the branch in a very imperfect state of maturity, and the want of richness and flavour in other forced fruits is often attributable to the same cause. The same great experimentalist records (*Hort. Trans.*, ii. 135) the result of his own management of a Peach-house, where a due regard was had to the preservation of a sufficiently low temperature at night. "As early in the spring as I wanted the blossoms of my Peach-trees to unfold, my house was made warm during the middle of the day, but towards night it was suffered to cool, and the trees were then sprinkled, by means of a large syringe, with clear water, as nearly at the temperature at which that usually rises from the ground as I could obtain it, and little or no artificial heat was given during the night, unless there appeared a prospect of frost. Under this mode of treatment the blossoms advanced with very great vigour, and as rapidly as I wished them, and presented, when expanded, a larger size than I had ever before seen of the same varieties, which circumstance is not unimportant, because the size of the blossom in any given variety regulates to a very considerable extent the bulk of the future fruit." It is, however, proper to add that the observations of Knight referred to a period when the principles of gardening were not generally understood so well as they now are.

The preceding remarks apply exclusively to plants in a state of growth. When growth ceases and fruit begins to ripen, circumstances in some instances wholly change.

In its favourite regions the Grape ripens its fruit at the hottest and dryest period of the year. In Corfu the Grapes are ripe in September. It appears from Dr. Davy's observations that the range of the thermometer in that island, day and night, is in August from 77° to 84°; and in September from 74° to 82°; that is to say, it is *never* colder at night than 74° in September, or than 77° in August. At Malta the *lowest* temperature observed in August was 74°; and in September 69°. In Candahar, Mr. Atkinson found Grapes ripe in June. The night temperature of Candahar in May and June is not given; but we may be very sure that in a country like

that, where a burning sun has been shining for three months, and the ground is excessively heated, there must of necessity be a very high temperature at night. In fact, in Persia, which is nearly the climate of Candahar, the midnight temperature of August has been known to be as high as 108°; and it is certain that in all such countries the difference between the temperature of the day and night, at the hot season of the year, when Grapes ripen, is inconsiderable. We may, therefore assume that a night temperature of from 70° to 80° ought to be secured when Grapes are ripening.

At that period of their existence much atmospheric moisture is unnecessary, or rather injurious to Grapes, for it will inevitably cause the Vine to break into a multitude of little branches to the impoverishment of the fruit. In the Vine countries the air is parching; Mr. Atkinson's paper curled up in Candahar, while he was writing on it; and the Vine will bear such a climate well, if it is gradually inured to it, *provided* the roots are in a *moist* soil, and there is a *free circulation* of air. It is to be recollected that when a tree is ripening its fruit, it is in quite a different condition from what occurs when it is flowering. At the latter period its energies are all directed to organizing itself, and consolidating the parts that may have been formed; it is growing, and hardening its growth. But at a later period organization and consolidation are accomplished, and it is the elaboration of the fluids, stored up within the plant, that has to be provided for. The fruit of such a plant as the Vine is incessantly sucking fluids out of the branches; but that fluid is little more than water and mucilage. It is after reaching the fruit that it thickens by evaporation, and changes owing to chemical combinations brought about by a variety of phenomena; the result of which is the conversion of acid into sugar, and the creation of the delicate flavours which give the Grape its value as a fruit.

CHAPTER XX.

OF SOIL.

The word soil signifies that portion of the crust of the earth in which plants grow; what lies below it is rock. It is to a great extent formed by the wearing down or decomposition of rock, with the addition of matters derived from the action of plants and animals, and from their decay. Soil, therefore, consists of two kinds of matter arising from different sources: one formed by the decay of rock is inorganic; the other originating in living things is organic. Clay or loam, sand, lime, and all the earthy or alkaline matters found associated with them, are inorganic. Peat, mould, and every thing which is convertible into these two substances, is organic. The supposed action upon vegetation of these kinds of matter has been scientifically investigated by all modern writers upon rural chemistry, to whose most valuable labours the reader in search of chemical facts will have recourse. In this place they will be regarded merely from a practical point of view.

Clay is a dense, plastic substance, pasty when wet, abounding in iron, tenacious of water, hardening and cracking when long exposed to dryness, and having the power of condensing ammonia and other gaseous matters. Its peculiar properties are chiefly owing to its containing alumina, a substance incapable, when pure, of supporting vegetation. In cultivated land clay always occurs mixed with sand or chalk, or both, in variable proportions. *Heavy clay* contains about 20 per cent. of sand; *loam* 50 or 60 per cent.; *calcareous loam* has a considerable quantity of lime (chalk) in addition; *fibrous loam*

contains the roots of herbaceous and fibrous-rooted plants in greater or less abundance.

The term "loam" (Angl. Sax. *Lam*) comes from an ancient word in different languages, signifying a fat, unctuous, tenacious earth. Under the name of "loam" there is comprehended a class of compound or mixed earths, composed of dissimilar particles—hard, stiff, dense, harsh, and rough to the touch—not easily plastic while moist, readily diffusible in water, and usually composed of sand and a tough viscid clay. Loams are very concisely divided into two kinds—the friable and crumbly sorts, composed of sand and a less viscid clay—and the tough and viscid in texture, that are composed of sand and a more adhesive clay. The colours have also been used to distinguish loams—the black and white, which are not acted upon by acids; yellow loams, some of which are affected by acids; the alkaline brown loams, that are acted upon by acids; and the green loams, that suffer no disturbance.

According to Woodward, loam consists of clay mixed with fine sand; or of clay with a superabundance of sand; and Bergman found a good loam to contain 87 per cent. of a reddish grey sand, as fine as meal, and 13 per cent. of alumina. Supposing clay to contain, as it most frequently does, 70 per cent. of fine sand and 30 of alumina, we shall find, as Mr. Kirwan observes, that loam of the best kind contains an excess of sand amounting to 17 per cent.; if the excess of sand be greater it will form a "sandy loam," if smaller, a "clayey loam." When anything calcareous is found in the loam, it inclines to the nature of marl, or a "marly loam," which may be either sandy or clayey, according as the proportion above indicated is exceeded on either side. But loams most frequently contain a portion of oxide of iron, which produces a considerable variety in the colour, and probably in the vegetative powers of the loamy earth, if its proportion be considerable, viz., 4 or 5 per cent.; they often contain, also, some proportion of sulphuric acid. The sandy part of the loam often has much effect in giving the colour. When gravels and pebbles are mixed with loams, the distinctions arise of "gravelly, stony, siliceous, and limestone loams," according as the substances predominate.

Loams are generally understood to consist of clay, siliceous sand, and some carbonate of lime. The quantity of iron, magnesia, and various salts, is so inconsiderable, as never to alter materially the texture of the loam. Decayed vegetable and animal matters in the form of humus are often found in loams in very considerable quantities, and the soil is fertile in proportion. Loams vary in quality; those composed of loose sand with little humus, and impregnated with iron, are very unproductive; those which contain too much clay, and lie upon an impervious subsoil, are difficult to cultivate. Between these two extremes there are soils that form the very best that are found on the face of the globe.

Loam seems to be naturally formed for the purposes of fertility; the pure earths are in themselves almost entirely barren; sands receive and discharge moisture much too quickly; clays retain it too long in their own substance, refuse it when wanted, and starve the roots of plants in a cold impervious mass; chalk has the same mechanical quality, and contains very little organic or soluble matter. Sand and clay alone would not make a rich soil, but a portion of calcareous matter and of humus being added, the mass is rendered open and porous, and the clay and sand are prevented from forming a mortar which hardens too rapidly, and prevents the influence of the air from reaching the roots. The invaluable quality of loams is that their texture allows the due circulation of air and moisture. Moist climates require a greater portion of sand to make a fertile loam, but less in proportion as humus abounds. All fertile soils contain some portion of calcareous earth. The climate of England requires one-half of the soil to be sand, one-third clay, and the rest chalk, to form a good loam, and rather light than heavy. Loams require less tillage than stiffer soils, and will bear more stirrings to clean them than sands—the produce is always certain and abundant. Every kind of manure can exert the proper action in loams, as they find a variety of substances on which to apply their influence.

The constituent parts of a good loam being correctly ascertained, and the deficiencies of inferior soils being also learned, it only remains to supply the wants in the latter as they appear from a comparison with the former. If clay be in excess, chalk and sand may be added; and a portion of the clay may be burned, in order to destroy the attraction for water, and thus act the part of sand in helping to form the loam. Limestone, gravel, and sand are also useful for this purpose, as they equally correct too great porosity, or too much tenacity. If there be too much sand in any loam, clay and chalk will be the remedy; and though the utmost art of man is able to effect "only" a mechanical mixture in place of the chemical combination of the substances that are sought to be amalgamated, yet the repeated stirrings which the land undergoes in the process of time doubtless tend to the most perfect blending of the matters to be assimilated.—*J. D. in G. Chron.* 1849, p. 628.

SAND consists of minute fragments of flint, or silica. It is white when pure, and is then called silver-sand, but is usually red or brown in consequence of the presence of iron. It has no power of cohesion, and therefore allows water to pass through it freely. In its natural state it is usually mixed with some portion of clay. It is more or less soluble in water holding alkaline matter or carbonic acid in solution; and

constitutes a portion, sometimes a most important portion, of the food of plants. For garden purposes that kind of sand is alone suitable which has been rounded in water. The angular particles of "road-sand" form hard impermeable masses, and should never be employed.

Shell sand is not sand at all, but rounded particles of carbonate of lime, fragments of shells and corals long rolled in water.

LIME occurs commonly in the form of its carbonate (*chalk*). It is to some extent soluble in water, and forms an important portion of the food of many plants, especially when combined with acids, as in the sulphate (*gypsum*), or the phosphate (*bone earth*). It readily dries, absorbs and detains heat, and has great value in modifying the wet tenacious quality of clay. In its caustic state it has the power of decomposing animal and vegetable substances, the result of which is a compound partly soluble in water, and peculiarly fit for the food of plants. It, however, requires to be used with caution, in consequence of the property it possesses of setting free ammonia, one of the most indispensable constituents of the food of plants.

PEAT consists of the dead remains of roots, branches, and leaves, mixed with various proportions of sand. It also commonly abounds in iron. When reduced to a powdery consistence by decay, it becomes *mould* or humus (*black mould, leaf-mould*). It has the important property of restoring alkaline matter to soil, of producing carbonic acid by slow combination with oxygen, and of aiding greatly in preserving soil in an open state, so as to allow water and air to pass freely through it. In the state of mould it condenses gaseous matter by virtue of its porosity.

These four kinds of matter are all that concern the business of the cultivator. Each, in its pure state, has little or no power of sustaining healthy vegetation; but when mixed in various proportions, they constitute the richest soils in the world. Hence it is that gardeners constantly employ a mixture of loam, peat, and sand, from which lime is only absent in appearance, abounding as it does in all good loam in the state of chalk. Nature demands no other means of sustaining

;etable life except clay, lime, and sand, with the aid of water 1 the gaseous matters of the atmosphere. Those gaseous .tters are nitrogen, brought to the land by rain, in the form ammonia, or of nitric acid (see page 29), and carbonic d, or other gaseous forms of carbon. Phosphoric acid and .phur seem to be sufficiently abundant in all sand or clay enable plants to exist at least, if not to grow in them with ;our; for although chemists, in their analyses, report in some ies only a *trace* of such substances, yet it must be remem- :ed that, as Dr. Daubeny has remarked, if only $\frac{1}{10000}$th :t may be present in a given sample of soil, yet even that presents more than 350lbs. as existing in the soil of an acre wn to the depth of a foot.

What the gardener tries to imitate is the soil in which plants naturally found in the greatest vigour. When he learns .t the pedunculate Oak always thrives best in strong clay, he ers that heavy clay is necessary to that kind of tree. If he :s that the Box-tree delights in chalky hills, and the Saint- n in chalky fields, he is justified in considering that cal- 'eous land is what they each prefer; and when he knows it fibrous-rooted plants, like Rhododendrons and Heaths, irish wherever peat and sand occur, he has recourse to it and sand for their cultivation. Nor is he to be censured this. On the contrary; even if his conviction that the ls in which plants grow wild are what suits them best should theoretically wrong, he at least knows that it is practically ht; and that if following nature closely shall not lead to the st possible results, it is sure not to lead him astray, provided has the skill to interpret natural phenomena with accuracy.

It is probable, however, that the influence exercised by soil on vegetation is due as much to its physical conditions as its chemical nature. At all events, I entertain no doubt it the former have been too much lost sight of in the search chemical evidence; and that in gardening, which is always cultivation of fertile soils, it is the subject which most nands attention. Soil, considered without reference to the ;anizable substances it contains, appears to act upon plants .efly by its power of absorbing and parting with heat and

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moisture. When soil is tenacious, or plastic, it absorbs heat slowly, and it parts with its water with great difficulty, as is the case in the London clay; the number of cultivated plants to which this is suitable is so small that it is almost expelled from gardens, where the object is to expose the cultivated species to conditions more favourable than those afforded them by nature. The small amount of bottom-heat afforded by clay, and the difficulty of draining it, sufficiently explain the badness of its quality for gardening purposes, even without taking into account the resistance experienced by plants in passing their spongioles through so compact a substance. On the other hand, loose sand, whose particles have no cohesion, although it imbibes water with great facility, parts with it as readily, and, being easily heated by the sun's rays, becomes so soon dried up as to be for that reason as unsuitable to most plants as the worst plastic kinds of clay. It is by obtaining a mean between these extremes that the soil is formed most favourable to the growth of plants in general.

As has been already stated, the artificial soil of the gardener is for the most part a combination, in various proportions, of loam, sand, and peat. The loam is a source of fertility, and parts with water reluctantly; sand increases porosity; and peat, in addition to any manuring value it may have, at once prevents consolidation, secures free drainage, and enables delicate roots to spread without hindrance. If chalk is seldom or never employed by gardeners, except as a manure, it is because that substance is abundant in garden loam. They know by experience the best loam to be what is called calcareous, and that they always obtain, if possible.

It is by no means meant by the author that the whole use of such substances is dependent upon physical qualities; it is only suggested that their principal mode of action is such as has been described, and that the precise chemical condition of loam, sand, and peat, is of *comparative* unimportance in horticulture. With agriculture it is otherwise.

For example, it was once a general belief, and still is in some places, that a fruit-tree border could only be made by paring off the surface of an old pasture, and employing the sods after having been laid in a

heap till the live turf had perished. There can be no doubt about the excellence of this material, which is moderately rich, retentive of moisture, and yet permeable to air and water in all directions. But to destroy an old pasture in order to obtain this result, is an act of mere ignorance. The points to be attended to in forming a substitute for turfy sods are—1, to obtain an equivalent for the roots that penetrate sods in all directions, forming myriads of fine tubes, which convey air and moisture through the whole mass of earth; 2, to exclude every kind of matter which gives rankness to growth, as all putrid or putrefiable materials do. This can be done by imitating the roots of the Grass that formed the turf: a neglect of that precaution can only end in failure. The roots of Grass are merely underground straws, of a more compact texture than usual; the two are chemically, as well as organically, the same, so far as cultivation is connected with them. Replace roots with straw: stable litter, but little fermented, contains all the equivalents—organic matter, saline matter, an absence of azotized matter in excess, and mechanical properties. Provided proper soil is procurable, everything else is thus furnished; and this litter is better than even decayed leaves, because it keeps the soil more open. The difficulty consists in the thorough incorporation of the requisite materials. It is difficult to incorporate *long* litter with anything. It could be shortened by chopping, and then the difficulty would vanish.

The best way of preparing a substitute for a turf border is to procure a light calcareous loam, and incorporate it with a quarter of its bulk of tolerably fresh stable litter and horse droppings. This incorporation may be effected by turning the mass over a few times during the three or four months which are required to reduce the straw to a proper state of decay, and it is then fit for use.

In like manner peat, so extensively used for "American plants" is by no means essential to their health. They grow very well in fine sandy loam, in leaf-mould, or in any very loose soil which is *not* calcareous, provided it is damp at the time when they are in full growth. *Rhod. maximum* grows in damp deep woods (*A. Gray*) and on the borders of mountain streams and lakes, requiring cool and perennial streams for its nourishment and support (*Elliott*); *R. ponticum* thrives on the face of the oozy hill at the back of St. Leonards in soft loam. Captain, now Lieut.-Col. Monro, says, "*Rhododendron arboreum* grows on the Himalayas in disintegrated granite, mica slate, and gneiss, without anything approaching to peat. *Rhododendron nilagiricum*, a species first indicated by Zenker, and one I believe generally considered distinct from *arboreum*, does in the Neelgherries grow in a thin stratum of peat, which, however, is frequently not more than six or eight inches in depth, and consequently the roots must soon pass through it into the soil below. The finest mass of *Rhododendron arboreum* I ever saw was

within 500 feet of the top of Dodotolia, a hill 10,000 feet high, in Kumaon, between Almorah and Sireenugger, on the Bhaugeruttie river, growing in company with *Quercus Kamroopii*, and just above the Deodar. Here every possible variety of colour capable of being produced by a mixture of crimson and white was to be found amongst the Rhododendrons; the whole side of the hill was one blaze of colour. A thirst-exciting ascent, in the middle of the day, 23rd April, made me search eagerly for water, which I could only find in the shape of some unmelted snow on the north side of the hill in a shady nook, till I descended at least 5000 feet to the stream in the valley below." It is, therefore, clear that peat is by no means indispensable to such plants.

A gardener must attend to three points if he wishes to grow American plants well: 1, the soil must be loose and rich; 2, while they are growing there must be free and constant access of moisture without stagnation; and 3, there must be no chalk.—The soil must be light and rich. Peat is not insisted upon; on the contrary, our great growers expressly state that other substances will answer the same purpose, provided they are in the same mechanical condition. The reason of this is obvious. "American" plants have in all cases delicate hair-like roots, which remain for years without any considerable increase in diameter; such roots cannot find their way through a soil which offers much resistance to their progress. Sand, very sandy loam, and decayed vegetable matter intermingled form the soil that American plants demand. Peat is a good material, because it consists of sand and decayed vegetable matter; and any other mixture of the same kind will be also a good material. Decayed leaves, fragments of very rotten branches or roots, probably charcoal, and such matters mixed with sand, in order to prevent the soil from becoming too compact, replace it perfectly. The value of peat consists in its being a good natural mixture, readily procurable in large quantities, in many districts. The necessity for loam depends upon its power of retaining moisture longer than dead or decayed vegetable matter. Provided the requisite moisture can be constantly secured, loam ceases to have value. Standish and Noble recommend the following as an excellent compost:—"To two parts of sandy loam or peat, or in fact any sandy soil that does not contain much calcareous matter (American plants exhibit a great dislike to that), add one-fourth leaf-mould, one-eighth sand, and one-eighth rotten manure. If wanted immediately, the whole should be well beaten, and thoroughly incorporated before using. It would, however, be of great advantage to allow the mixture to remain twelve months, turning it well two or three times during that period. In old exhausted beds, a good dressing of rotten manure forked in will be found highly beneficial."

There must be free and constant access of moisture, without stagnation. In American plants the roots are much more quickly dried than those of other plants. They are not thick, fleshy, cellular

masses, coated with a spongy bark capable of detaining moisture with great force. On the contrary, they are, as has been already stated, delicate hair-like fibres, whose bark is little more protection to them than the skin of a leaf. Such being their structure, they are emptied of whatever fluids they may contain when the earth in contact with them becomes dry; and if in a growing state they necessarily perish. All those directions, therefore, which insist upon keeping the level of American beds below the surrounding surface, when the situation is not naturally damp, are founded upon a correct appreciation of the nature of these plants. Why calcareous matter in excess should be offensive to them we are unable to explain. Such is the fact; and it is probable that the reason why the American plants at Knap Hill and Bagshot are finer than any in the valley of the Thames, is on account of the great abundance of lime in the water of all the latter district. It appears from analysis that while London water, that is to say Thames water, contains 16 grains of lime in a gallon, Bagshot water contains only one grain, or less. The true difficulty, then, in growing American plants, is not the want of proper soil, for that may be made, but the want of a sufficient supply of pure water; and it may be a question whether a very material difference would not be found in those places where American plants grow badly if rain-water alone were used in watering them, instead of that from pumps and ditches.

It is as well to observe that the peat from bogs is not suited to garden purposes, until it has been rotted down by long exposure to weather, or by the action of lime or caustic ammonia (gas water). This is owing to the large quantity of free acetic acid and tannin in its composition, which renders it unfit to support vegetation till the acid is neutralised and the tannin decomposed. Another way of rendering it a fit substitute for the upland peat, which gardeners prefer, is to ferment it in a heap, mixed with stable litter; if moistened with gas water, so much the better; in a twelvemonth it is fit for use, with the addition of loam and about 80 per cent. of silver sand.

When we see that the Box-tree, the Fig-tree, the shrubby *Bupleurum* delight in chalky hills, it is inferred that chalk is necessary to those plants. But they will also grow in clay, though not so well; and it is possible that they may prefer the hills they live on, because they are hot and dry, not because they are calcareous. *Elymus arenarius* lives in blowing sand; but it may occupy that soil because of its extreme looseness and dryness, not because of its being siliceous. Epiphytes do not grow in earth; apparently because the peculiar organization of their roots renders them impatient of having those parts covered; and they prefer the branches of trees to rocks, not

perhaps because of any peculiar food which they find on trees, but because wood is a bad conductor of heat, and because they find shade among branches, while rocks conduct heat more rapidly, and are exposed to more dryness or to more wetness. If rocks are soft, shaded, and so placed as to be exposed to no sudden changes of temperature, then Epiphytes grow as well on them as on trees.

Dean Herbert, a most acute and experienced gardener, held that PLANTS DO NOT GROW NATURALLY IN THE SOIL BEST SUITED FOR THEM. He contended that the reason why many plants are found in peculiar places is not at all because they prefer them, but because they alone are capable of existing there, or because they take refuge there from the inroads of stouter neighbours who would destroy them: and consequently he by no means advised the gardener to imitate, in a servile spirit, all that he saw happening in the abodes of wild vegetation.

"I saw," said the Dean, "a Crocus, a Sternebergia, and an Ornithogalum growing in contact with each other aloft on the meagre sod of Mount Œnos; but not a seed-pod of the Sternebergia could be discovered, and very few of the Crocus. In a more fertile sod they would have been choked by some stronger plant, but they would rejoice in a better soil, if protected against the oppressor. * * * The compost in which the Dutch raise their improved bulbs of various kinds is known to be (see Sismondi, des Jacinthes) a compost of humus, obtained from thoroughly decayed Elm-leaves and dung of stall-fed cattle, and mixed with sand deposited by the sea on a bed of prostrate timber of unknown antiquity, in which there is probably nothing calcareous. Does it not then appear that the case stands thus—not that calcareous matter is essential to the growth of Crocus, or even a useful auxiliary, but that Crocus can bear the sterility of elevated calcareous mountains better than most other plants of stronger growth? If that be true of one genus, it will probably be applicable to others. * * * It will be found that Orchis latifolia, removed from the swamp, in which it struggles with other swamp-plants, will grow more vigorously where it is cultivated with less wet. The small Polygala vulgaris is stated in Mr. Babington's Manual to grow

in dry pastures, having flowers either blue, white, or red. I believe the stated habitation to be only thus far true, that it does not grow in water. I do not recollect seeing it in sandy pastures; I know it well on chalk and on clay. In England it is little admired. In the alluvial and very moist meadows of Zante, near the sea, in the vicinity of Trieste, it formed a most conspicuous part of the meadow-crop at the end of May, and the beauty with which it painted the herbage was to me astonishing. It seemed that, in a warmer climate, it could endure more moisture than with us. On the slope of Monte Spaccato, where no Grass grows, large single plants of it stood in the bare soil amongst the stones, with every intermediate diversity of pearl-colour and lilac, showing evidently that the merits of that little plant under cultivation are not appreciated or known."

We believe that in this instance the views of Dean Herbert were in perfect accordance with every well ascertained fact relating to other plants; and that one of the greatest errors that have been committed is an unintelligent imitation of soils. Men do not, in fact, distinguish between natural *accidents*, such as soil, and natural *habits*, such as manner of growth coupled with atmospheric peculiarities. It is the natural *habit* of the Sikkim Rhododendrons to grow in a damp atmosphere, highly charged with the results of frequent thunderstorms; and they may never be grown well except in the presence of such conditions or of their equivalents. But the growing upon the branches of trees is with them an *accident*, and they grow quite as well if not better in soil; for there is nothing in the anatomical condition of their roots which declares that in air alone are they capable of existing.

A striking example of this is given in the *Botanical Magazine*. Speaking of the management of the Lace-bark tree, Mr. John Smith says: "Mr. Wilson informed us that 'it is invariably found growing in very dry situations on marly limestone hills, where there is not a particle of earth to be seen. The young plants grow in the crevices, or *honeycomb*, as it is called, and in order to obtain them with roots, a hammer or large stone is required to break away the porous limestone.' He further adds, that 'the soil for growing it in should be composed of one-third marl or lime-rubbish; for I am persuaded that pure loam

will kill them.'" But Mr. Smith observes: "In our experience, we have never found any plant thrive by retaining it in its native soil, or in soil too closely resembling it. If we could also imitate all the various influences of climate that modify and control the growth of plants in their native localities, it might then be proper for us to cultivate the Lace-bark tree in marly soil, like limestone; but our plants afford evidence that such soil is not required when they are grown in an artificially heated atmosphere. We have used good yellow loam, mixed with a little leaf-mould and sand. In this they have attained the height of 8 feet, and continue in a perfectly healthy state."

This opinion is greatly supported by such facts as the following, which show that great numbers of plants have no particular predilection for soil, or at least, that if they have we cannot show it to exist, and that there are facts in the relation between plants and soil which remain without explanation. Mr. Knight observed that varieties of the same species of fruit-tree do not succeed equally in the same soil, or with the same manure: the Peach in many soils acquires a high degree of perfection, where its variety, the Nectarine, is of comparatively little value; and the Nectarine frequently possesses its full flavour in a soil which does not well suit the Peach. The same remark is also applicable to the Pear and the Apple; and, as defects of opposite kinds occur in the varieties of every species of fruit, those qualities in the soil which are beneficial in some cases will be found injurious in others. In those districts where the Apple and Pear are cultivated for cider and perry, much of the success of the planter is found to depend on his skill or good fortune in adapting his fruits to the soil. (*Hort. Trans.*, i. 6.) Rhododendrons and Kalmias are usually cultivated in peat earth mixed with sand, and yet they grow as well in fresh hazelly loam, without any mixture whatever; and, than these two kinds of soil, none can be apparently more dissimilar. The fine American cottons are grown in a calcareous sand, those of India in a deep black saponaceous earth; the American cotton will not thrive in the latter, nor that of India in the former, as has now been ascertained; and yet the species of Gossypium producing the two qualities have no organic differences which can, so far as has yet been ascertained, explain in the smallest degree the necessity, under

which it is evident that they labour, of being provided with different kinds of food. The Alnus glutinosa, or Common Alder, flourishes in wet clayey meadows; while Alnus incana, or Upland Alder, is equally suited to a dry and light land: we are totally ignorant of the reason of such a case as this. Rhododendron hirsutum and Erica carnea are, in their wild state, confined to calcareous soil; while Rhododendron ferrugineum grows exclusively on granite, and Erica vagans on serpentine. We are informed by Beyrich (*Gardeners' Magazine*, iii. 442) that "the Pine-apple, in its wild state, is found near the sea-shore; the sand accumulated there in downs serving for its growth, as well as for that of most of the species of the same family. The place where the best Pine-apples are cultivated is of a similar nature. In the sandy plains of Praya velha and Praya grande, formed by the receding of the sea, and in which no other plant will thrive, are the spots where the Pine-apple grows best. The cause of this lies evidently in the composition of the sand, which chiefly consists of salt, lime from decomposed shells, and a very little vegetable mould. Warmth, lime, salt, and moisture seem therefore to be the principal ingredients in which the Pine-apple thrives. Sand will take a very high and continued degree of warmth, being often heated by the sun so much as to scorch vegetation, and yet it seldom dries to a greater depth than from eight inches to one foot; sea salt is well known for its property of attracting the nocturnal damps, and retaining them a long time. The lime of the shells seems to be the principal manure, which has also been proved by the English here, who, by manuring their Pine-apples with a mixture of stamped oyster-shells and vegetable earth, produce very large fruit. The natural mould, usually slightly mixed with sand, is partly of a vegetable and partly of a mineral origin." But it is well known that the Pine-apples of England are much superior to those of South America, and yet English gardeners grow their plants neither in sand, nor saline, nor calcareous soil. Moreover we learn from Mr. Campbell Lees that in the Bahamas the Pine-apple will neither grow in decomposed Madrepore limestone, nor in light deep black vegetable soil; but that it thrives exclusively

in a red soil, which Professor Edward Solly found to be chiefly remarkable for an unusually large proportion of oxide of iron. (*Journ. of Hort. Soc.* i. 126.)

On the other hand we know that salt plants, like *Nitraria,* will not thrive in the absence of the salt soil in which they naturally grow; and that others, such as Samphire, the garden Pink, the Red Valerian, the Sea Beet, are much improved in health by its presence, to say nothing of Salicornias, and other purely salt plants, which will not grow in saltless land. Chalk also appears to be fatal to the healthy growth of others, such as Rhododendrons, and some Conifers; while Beech and Box prefer it. Clay again, which is invaluable as a soil for *Quercus pedunculata,* is ill suited to *Q. sessiliflora,* and will not grow Heaths at all. Therefore the opinion that the soil which plants inhabit when wild is not necessary to them, requires a good deal of qualification.

In like manner plants grow naturally and remain healthy in places where no manure can reach them. But they are not benefited by the absence of such agents; on the contrary, even Mosses and Lichens flourish most where they are best fed, and plants inhabiting peat, sterile as that soil is, feed greedily and thrive greatly when well manured. Of this a striking instance is furnished by Bagshot heath.

> A more unpromising appearance than that originally belonging to the present American nursery at Bagshot, can scarcely be imagined. In its present improved state, it affords a good example of what can be done in the most sterile spots. The ground in question forms part of 50 acres, the whole of which is rated in the poor's-rate book at 8*l.* The soil, which is from 12 to 15 inches in depth, is a black sandy peat, resting upon a clayey subsoil very deficient in vegetable matter, and naturally incapable of producing any crop. With cultivation it has been rendered in the highest degree productive. The first operation was to drain it from 3½ to 4 feet deep; it was then trenched 2 feet deep, and to every acre so treated, from 30 to 40 tons of good farm-yard manure was added; and as a precautionary measure, in order to exhaust the rankness attendant upon this treatment, it was deemed necessary to take off the land a root crop of Potatoes, Carrots, Turnips, and Mangel Wurzel. After this treatment, American plants were found to thrive amazingly; but, like all crops in very poor soils, they continue to be benefited by the application from time to time of suitable enriching materials.—*Standish on American Plants.*

CHAPTER XXI.

OF MANURE.

To manure a plant is to feed it artificially.

We see that plants and animals exist in a wild state without the aid of any other food than what is presented to them spontaneously. There is everywhere around us a bountiful provision for sustaining life. Providence has created animals and plants to be fed on by man, animals prey on animals and plants, plants subsist upon the decay of animals and plants; and these mutual relations are so nicely adjusted, that we have no reason to suppose that any one species has disappeared since the creation from want of food. When species have perished they have been exterminated by man.

But although plants are surrounded on all sides by the materials necessary to sustain life, yet when man invades their haunts and turns them to his peculiar purposes, natural circumstances no longer suffice. Water and air and what belongs to them remain indeed as before, but the food provided in the soil becomes exhausted; when the races of plants are altered by domestication they require more abundant nutriment; and to obtain from the earth a greater produce than it can yield spontaneously becomes a matter of the first necessity; hence arises the application of manure, which is to the vegetable kingdom what artificial feeding is to animals.

The object of manuring is either to increase the fertility of land, or, if fertile by nature, to keep it in that state by continually returning to it the substances which crops may have removed. If a tree advances in the course of time from a mere

point till it acquires the weight of many tons, it does so by gradually absorbing from the earth and air such food suitable to its nature as is found there. What is derived from the air may be disregarded, the constituents of the atmosphere being ever renewed and inexhaustible; but inorganic matter, presented to our eyes by the ashes of the tree when burnt, is wholly derived from the soil, which is neither ever renewing nor inexhaustible. Should the tree perish where it stood and there decay, the soil would receive back all that it had given up, and no exhaustion would have taken place. But if the tree is felled and carried away, then the soil is robbed of all the inorganic matter which entered into the composition of the timber, and becomes *pro tanto* exhausted of its nutritive powers. The matter thus removed is restored by manure. And so of all plants else. Such is the inevitable result of cultivation.

Although it is unquestionable that all cultivated plants require manure, on account of the exhaustibility of all soils, sooner or later, yet it must be remembered that the rate of exhaustion depends upon the proper nature of soil, and the treatment it receives at the hands of the gardener. Sandy soils are rapidly rendered barren by cropping without manure; clayey and loamy soils much more slowly. And when the latter are skilfully cultivated crop after crop of certain kinds of plants may be taken from them with no apparent loss of fertility. This has been strikingly illustrated by the Rev. Mr. Smith, an accomplished agriculturist residing at Lois-Weedon, a remote village on the oolitic clay of Northamptonshire, where repeated crops of wheat, at the rate of 40 bushels an acre, have been obtained for many years successively, without manure, by mere spade cultivation. This gentleman thus succinctly describes his mode of tillage (the land being of course thoroughly drained):—

"At the outset I plough the whole field early in autumn an inch deeper than the staple, harrow, and roll, and harrow again—pulverising and preparing it, in short, as for Barley. I then get in my Wheat, leaving yard-wide fallow intervals between the rows. When the Wheat is up I begin to dig, which is done thus:—At the end of the interval I first throw out on the headland about 3 feet of soil to the entire depth I intend to go the first year, and, supposing the staple to be 6 inches, and the 4 inches of subsoil to be clay, this depth altogether will be 10 inches. The spadesman now, with a shallow spit, casts the 6 inches of staple to the bottom of the trench of this yard length of interval; and then, with another spit still shallower, throws the 4 inches of the subsoil lightly on the top, and so on all over the field.

This process is clearly accomplished at two diggings. My object in thus keeping the pure subsoil separate and unmingled on the surface, which no single digging to the same depth could do so effectually, is to enable the atmosphere during winter to have its full and unobstructed influence on the clay; and when this effect has been produced, as it will be found to be in spring, these important results will have ensued:—The clay will have crumbled down to dust, a portion of its known mineral constituents will have been rendered soluble, and it will be brought into a condition to receive and retain the organic elements of fertility contained in the atmosphere. It is only after this that the horse-hoe in the summer well mixes the now pulverised clay with a portion of the staple below, and fits the land for the following crop. In the third and fourth years (the other moiety of the field having gone through a similar process the second year) an inch more of the subsoil is brought to the surface; and so on year after year till a depth be attained by inch degrees, of 20 or 24 inches, 'beyond which it is neither needful nor convenient to go.' The principle of the practice being that no more of the subsoil be brought to light than can be wholly pulverised before it be mixed with the staple, it is evident that, in the end, after many years of gradual deepening, and repeated stirrings throughout each year, the entire depth of these two full spits will have become friable as garden mould." *

Although this is an Agricultural fact, it is one equally applicable to Horticulture; for it shows that by constantly exposing oolitic clay to the action of the atmosphere, as much inorganic matter suited to the food of wheat is annually set free in the soil as is removed by the crop; and that where doses of azotised manure are not required, deep and careful cultivation has a better effect than mere manuring.

On the one hand, with shallow cultivation, puddled furrow-trenches, and polished furrow slices, rain-water highly charged with the most nutritious ingredients either runs off to ditches, or is so ill-directed that it very imperfectly reaches the roots. On the other hand, by means of close cropping, that which is intended to bathe every part of a plant, and to be instantly absorbed by its verdant surface, is turned aside. But at Lois-Weedon the soil is made so deep and kept so open, that every root is certain to receive its allotted share of the invigorating shower, and before the rain-water finds its way to drains, it has given up its fertilising ingredients either to the living suckers, for which they were intended, or to the soil which detains them till they are wanted. There, too, the plants are so widely spaced, that no one row intercepts what is intended for another. Even when manuring is indispensable, the effect of the manure is much increased by the same kind of cultivation. Turnips and similar root crops have 5 feet for every plant to

* For full particulars of this practice, see *A Word in Season; or How to Grow Wheat with Profit.* 12th ed. London, 1854.

spread in; the lines of wheat are a yard asunder, and catch all the rain or dew that descends upon them; and thus half an acre of heavy clay land brings six or seven quarters of Beans, or twenty-seven tons of Swedish Turnips; and would carry Carrots, Cabbages, Celery, and Onions, in similar proportion if it were a kitchen garden.

It may be added, that by a similar process were obtained some magnificent British Queen Strawberries, exhibited a few years ago, at Chiswick, by the Speaker of the House of Commons, which the spectators fancied that the right honourable gentleman must have raised by excessive doses of guano.

Under natural circumstances exhaustion is provided against by the decay of plants where they stand, the soil thus receiving back from the dead not only what it yielded up to the living, but as much more as the living were able to solidify at the expense of the atmosphere. And hence the extraordinary fertility of the soil of some virgin countries. When nature causes the tree to shed its leaves, it is not merely because they are dead and useless to the tree, but because they are required for a further purpose—that of restoring to the soil the principal portion of what had been abstracted from it during the season of growth, and thus of rendering the soil able to maintain the vegetation of a succeeding year. Every particle that is found in a dead leaf is capable, when decayed, of entering into new combinations, and of again rising into a tree for the purpose of contributing to the production of more leaves, and flowers and fruit. If the dead leaves, which nature employs, are removed, the soil will, doubtless, upon the return of spring, furnish more organizable matter without their assistance; because its fertility is difficult to exhaust, and many years must elapse before it is reduced to sterility. But the less we rob the soil of the perishing members of vegetation which furnish the means of annually renewing its fertility, the more will our trees and bushes thrive; for the dead leaves of autumn are the organic elements out of which the leaves of summer are to be restored in the mysterious laboratory of vegetation. They contain the carbon or humus, and the alkaline substances essential to the support of growing plants; and although such substances can be obtained from the soil, even if leaves are abstracted, yet they can never be so well obtained as through the decay of those organs.

For these reasons the practice of removing the leaves which fall in shrubberies, in order to preserve neatness, cannot be too much condemned. Such leaves, when dried, contain from 5 to 10lb. of inorganic matter, suited for the food of plants, in every 100lbs.; and this is generally enclosed in a vegetable tissue, which runs rapidly to decay. It is only otherwise with the hard leaves of certain resinous evergreens, such as Pine-trees. Neatness, no doubt, must be observed; and this will be sufficiently consulted if leaves are swept from walks and lawns, and cast upon the borders in heaps, where they may lie and decay till the winter has arrived, when they can be spread upon the earth like so much manure.

The subject of manures has been most fully and ably treated in both a theoretical and agricultural point of view by a great number of accomplished chemists, whose works of themselves form a small library,* to which the reader is referred. In this place it would be superfluous, even were it possible, to present any other than the slightest possible sketch of so great an enquiry.

In considering the action of manure there are two points which more especially demand attention—the one, what constitutes the more important part of the food of plants in general: the other, what special food certain kinds of plants are known to

* Among these may be more particularly mentioned the following;—

Anderson, in the *Journal of the Highland Society*.

Boussingault, *Economie Rurale considérée dans ses rapports avec la Chimie, la Physique, et la Météorologie.*

Dana, *A Muck Manual for Farmers.*

Daubeny, *Three Lectures on Agriculture, Papers in the Journal of the Agricultural Society*, &c.

De Gasparin, *Cours d'Agriculture.*

Dumas, *Chemistry of Organic Life.*

Johnson, J. F. W., *Lectures on Agricultural Chemistry*, and *Agricultural Chemistry.*

Lawes, *Various Papers in the Gardeners' Chronicle, Journal of Royal Agricultural Society, Transactions of British Association*, &c.

Liebig, *Chemistry in its Applications to Agriculture and Physiology.*

Mulder, *Chemistry of Vegetable and Animal Physiology.*

Payen, *Chimie Industrielle.*

Playfair, in *Morton's Encyclopædia of Agriculture.*

Schübler's *Agricultur-Chemie.*

Solly, E., *Rural Chemistry, and Various Papers in the Transactions of the Horticultural Society*, &c.

Sprengel, *Chemie der Pflanzen, Bodenkunde, Lehre von Dünger, Lehre von den Urbarmachungen.*

Völcker, in *Morton's Encyclopædia of Agriculture.*

Way, in *Morton's Encyclopædia of Agriculture*, and in the *Journal of the Royal Agricultural Society.*

thrive upon. The first has been already very slightly adverted to (pp. 28 and 29), but must now be more fully examined.

Nothing can be taken into the system of a plant while in a solid state. To be suited to absorption, it is indispensable that matter should be gaseous, or fluid, or soluble in water.

The most important GASEOUS SUBSTANCES are—1, *Carbonic Acid;* 2, *Nitrogen;* others may be practically disregarded.

Carbonic acid. When a plant is exposed to high heat, it is soon reduced, however delicate it may be, to a brown or black substance. That substance is charcoal, which constitutes by far the larger part of all vegetable structure. Charcoal is assimilated by plants from carbonic acid, in which all atmospheric air abounds; the carbon or charcoal is separated by vital force, and the oxygen is liberated.

Carbonic acid is formed slowly by all animal and vegetable substances undergoing decay in the presence of moisture; hence in part the manuring value of decaying leaves, of vegetable mould, of the excrements of animals, &c.

It has been doubted, indeed, whether it is by the formation of carbonic acid, that decaying vegetable matter acts beneficially, and it has been imagined that what is called humic acid, formed from decaying mould by the action of alkalies is taken up directly by plants as food. Opinion is generally unfavourable to this theory; and since we know from the experiments of De Saussure and others, and it is not indeed denied, that dead vegetable matter disappears in consequence of its gradually combining with oxygen, and forming carbonic acid, there is no necessity for looking to some supposed action of *humates* in order to account for the manuring value of vegetable substances in a state of decay.

It has been found that charcoal itself is highly beneficial when introduced into the soil, and it has been inferred that even charcoal acts by its property of assuming a gaseous form when combined with oxygen. But chemists believe that it is rather by virtue of its porosity, whence it derives the power of condensing gaseous matter, and slowly parting with it again, that charcoal acts beneficially. According to Mitscherlich, "the cells of wood-charcoal have a diameter of about $\frac{1}{2400}$ of an inch, and if a cubic inch consisted entirely of cells, their united surface would amount to 100 square feet. By expe-

riment it can be shown that the cells constitute $\frac{5}{8}$ths of the whole cubic contents of the charcoal; and allowing for the space occupied by the charcoal, the actual surface of the cells would be about 73 square feet. When charcoal is plunged into carbonic acid gas, it absorbs into its cells no less than 56 times their cubic contents at the ordinary temperature and pressure, and consequently the gas is condensed to 56 atmospheres. But according to the experiments of Adami, carbonic acid liquefies under a pressure of 36·7 atmospheres, and we are hence compelled to conclude that above one-third of the carbonic acid which is condensed on the walls of the cells is in the liquid state."

Of late years a great deal has been said of the value of charcoal in soil. Experiments have shown that in powdered charcoal alone plants flourish with an extraordinary degree of vigour; charcoal has been recommended as the best of substances in which to strike cuttings, and by degrees it has gained a reputation which nothing now can shake. It is true that some experiments with it have failed, owing, probably, to its having been used in too fine a state, or to other accidental causes; nevertheless, the opinion of practical men is setting steadily in its favour. Messrs. Loddiges employed it advantageously in the cultivation of Orchidaceous plants, charring the wooden blocks on which they are attached: that practice was introduced beneficially at Chatsworth, and nothing can be more striking than its good effects in other gardens, where a few weeks suffice to give a dark green healthy colour to the plants attached to charcoal blocks. By mixing it with the soil of Orange-trees their health is increased in a remarkable degree; and it is used largely as an ingredient in the soil employed by Mr. Barnes for the production of the fine Pine-apples of Bicton. This may be in part ascribed to the mechanical action of charcoal, and to its freedom from insects; or, as chemists maintain, it may be owing to the power possessed by charcoal of *condensing* within its pores carbonic acid and other gaseous substances which are slowly yielded up to plants as they are required; or it may arise from a slow formation of carbonic acid, as Mr. Rigg ascertained to occur; for in six weeks he obtained more than half a cubic inch (.64) of carbonic acid from 50 grains of soft Elm charcoal; and we know from experience the softer the charcoal the better it is suited to cultivation; as indeed is shown by *Peat charcoal*, a most valuable substance for gardeners.

Fortunately it matters little in practice whether charcoal acts beneficially on plants by forming gaseous compounds from its own substance, or by seizing them from the atmosphere, locking them in its pores, and then releasing them as plants require them for their food. That it does

feed plants, and most abundantly, is proved by evidence that cannot be controverted.

"The great utility of *charcoal and wood ashes*," writes a correspondent of the *Gardeners' Chronicle*, "being admitted on all hands for gardening purposes, I would direct attention to the necessity of a somewhat systematic course of procedure in the mode by which it is made. Whilst the felling of trees, the 'stocking' of hedges, or thinning of woods are proceeding, is the time to lay in a considerable stock for the year. The process of burning is most simple. I begin by burning all the largest of the brush as a centre of operations; following up with the smaller wood; and when in a due state of combustion, covering the whole with a rough refuse of the kitchen garden, which has been twelve months in collecting. Finally, a coating of turves or soil—double if turves; the latter being reserved for prime potting purposes. The material thus managed will furnish large masses of charcoal for Orchids, &c.; smaller lumps for drainage to pots; and wood-ash in abundance for dressing seed-beds, for any plants which require fresh material."

Being heavier than atmospheric air, carbonic acid has a constant tendency to fall to the earth and to settle down among its crevices, even if it is not carried thither in water. Hence we find it abundantly in wells, drains, old sewers, and similar places, in which, if moisture be present, roots develope with prodigious rapidity. (See page 20.)

Boussingault and Léwy have ascertained experimentally that the quantity of carbonic acid in the soil is very much beyond what has been supposed, especially if it has been recently manured, as appears from the following statement:—

In its normal condition atmospheric air contains .0004 in volume of carbonic acid. In soil, on the contrary, twelve months after the application of manure, from 22 to 23 times as much were found, and in land recently manured as much as 245 times in weight. If, however, the object is to ascertain the quantity of carbonic acid that is placed at the disposal of the plants growing in the soil, the proportion contained in the air confined in its pores will not suffice. It is necessary, then, to know the quantity of air in a given volume of earth. This volume may be easily estimated by saturating the soil with water, as the volume of air displaced will exactly equal the volume of water introduced. Some of the main results of the experiments, instituted for this second object, are stated by the authors as follows:—

1. The air inclosed in a hectare (10,000 square mètres, 11960.33 square yards) of arable land, one year after being manured, contains as much carbonic acid as 18,000 cubic mètres of atmospheric air. That is to say, inasmuch as taking the average depth at 35 centimètres (about

14 inches), the hectare contains 3500 cubic mètres of soil, the carbonic acid in the soil in proportion to that in the air, volume for volume, is as 36 : 7.

2. In the same quantity of land recently manured, the carbonic acid, under certain circumstances, may be represented by that contained in 200,000 cubic mètres of normal air, or in the proportion of 400 : 7.

3. In the loamy subsoil of a forest, taking the average depth, as in the former instances, the amount is that contained in 5000 cubic mètres, or as 10 : 7. There are of course more or less especial cases, for every shade of difference is capable of occurring under peculiar data. In the sandy subsoil of a forest, for instance, the proportion, as compared with the loam in No. 3, was only as 1 : 2.76.

Nitrogen, or *azote*, abounds in all the young parts, especially while in rapid growth; as organs become old it disappears. It is evidently connected with high vitality, whatever its exact action may be; and is as indispensable to the growth of a plant as carbonic acid itself. The atmosphere consists of 79 per cent. of nitrogen and 21 per cent. of carbonic acid. But whether or not plants obtain their nitrogen in its pure state from the atmosphere is uncertain. There is no doubt, however, that in the form of ammonia (an acrid gaseous compound of nitrogen with hydrogen) it is eagerly consumed, provided it is first reduced to the state of a soluble salt so as to lose its causticity. The carbonate, sulphate, muriate and nitrate of ammonia are all common forms of the substance, and being soluble in water are readily absorbed by all parts of the live surface of a plant. Lime has the power of decomposing these salts and setting free their ammonia, for which reason lime should never be used in conjunction with them. Nitric acid (a compound of nitrogen with oxygen) is also another source of this element, whence arises the great manuring value of nitrates; it exists abundantly in the atmosphere, as is shown by the experiments of M. Barral, quoted at p. 29.

Like carbonic acid, ammonia is condensed and detained in porous bodies. Mr. Way was the first who drew attention to the remarkable power which soils generally have of absorbing ammonia and its salts. It had always been believed that all porous soils possessed the power of condensing ammonia, and it had likewise been long known that, in addition to this, which might be called a merely mechanical effect, certain soils possess the power of absorbing or fixing ammonia, in consequence

of certain chemical agents present in them; but other facts seemed to point to some physical property belonging to most soils, in consequence of which they possessed these powers. Mr. Way's experiments show the great absorptive power which the soil has; and give us some evidence of the mode in which this power practically operates. It appears that, if strong liquid manure, or a strong solution of ammonia in water, is filtered through a portion of soil, the ammonia will be absorbed, and the liquid which passes through will be found to contain no ammonia. It is plain, therefore, that the small quantity of carbonate of ammonia which rain-water usually contains, will be absorbed by the surface soil, and that in a very heavy shower of rain, sufficient to render the soil thoroughly wet to a considerable depth, there is no fear that the ammonia thus supplied to the soil will be washed away by the continuance of the rain. "It is also evident," says a writer in the *Gardeners' Chronicle* "that, when land is flooded, the ammonia which the water contains will be for the most part arrested by the soil over which it flows. The great fertilising effects produced in Egypt by the waters of the Nile, in its periodical floods, were no doubt partly due to this cause; the benefit resulting not from the small quantity of slimy mud which the water left behind, but from the saline matters which it brought with it, and which were absorbed and retained by the surface of the soil as the water flowed over it. Mr. Way's experiments show that a good soil (one which contains a reasonable quantity of clay, which is essential to this effect) has the power of thus absorbing or fixing ammonia in whatever state that substance is presented to it; it is the same whether the ammonia is in its free and uncombined form or whether it is united to some acid constituting a neutral salt. In the former case the ammonia is directly absorbed, and the water passes off entirely deprived of it; in the latter case the salt appears to be decomposed under the influence of this peculiar power of absorption, the acid with which the ammonia was previously combined uniting to lime or some other base present in the soil."

Wherever animal matters are decaying there ammoniacal gas is evolved. Thrown into the air in the form of a carbonate, it is immediately dissolved in the vapour eternally present, and when that vapour is precipitated as rain it is conveyed to the earth and to all the foliage that intercepts it. Absorbed by the leaves, sucked up by the roots, it adds intensity to the green colour and vigour to all the powers of vegetation. How it acts is immaterial; that it does act, and with admirable effect, is now undoubted.

"The nitrogen of putrefied animals," says Prof. Liebig, "is contained in the atmosphere as ammonia, in the state of a gas

which is capable of entering into combination with carbonic acid, and of forming a volatile salt. Ammonia in its gaseous form, as well as all its volatile compounds, is of extreme solubility in water. Ammonia, therefore, cannot remain long in the atmosphere, as every shower of rain must effect its condensation, and convey it to the surface of the earth. Hence, also, rain-water must at all times contain ammonia, though not always in equal quantity. It must contain more in summer than in spring or in winter, because the intervals of time between the showers are in summer greater; and when several wet days occur, the rain of the first must contain more of it than that of the second. The rain of a thunderstorm, after a long-protracted drought, ought, for this reason, to contain the greatest quantity conveyed to the earth at one time."

This fact has been occasionally applied to the improvement of the air of glass-houses, by manuring plants through their leaves. When the philosopher of Giessen demonstrated the important truth that ammonia is derived from the atmosphere, a new light was thrown upon the refreshing and invigorating effect of heavy rains, which act, not merely by their water, as once was thought, but also by the carbonate of ammonia which they bring down. So far as agriculture is concerned this is, however, a truth devoid of possible application, because the volatile carbonate cannot be advantageously used, artificially, through the agency of the atmosphere. But it is otherwise with gardeners, who have to create an artificial atmosphere in a confined space. It is not a little remarkable, then, that so simple an agent, so easily procured, and applicable with so little trouble, should have scarcely ever been employed in hot-houses in the proper manner. Where it has been used it has been almost invariably when dissolved in water, and applied with a syringe.

The carbonate of ammonia of the atmosphere is suspended, dissolved in invisible vapour. In this state it is incessantly in contact with every part of the foliage. When rain falls, the ammonia disappears for the moment, passing downwards in the rain-drops to the ground, and thence arriving at the roots of plants. But if it is in gardens first dissolved in water, and then thrown upon plants with a syringe, natural conditions are by no means imitated. It reaches no part except that on which the water falls, half the upper surface and nearly all the under surface of the foliage is missed, and it is scarcely detained even upon the parts which the water actually touches. The proper course is to throw it into the air in the form of gas. This is easily effected in the following manner. When a greenhouse or hothouse is shut up, warm

and damp, rub upon the heated pipes, the flues, or a hot piece of metal, a small piece of carbonate of ammonia *with some water* (not dry); the peculiar smell of smelling salts will be instantly perceived, and if this is done at the two ends of a house, as well as in the middle, the air will rapidly receive a sufficient charge of the substance. After it has been allowed to remain about the plants for a short time, some gardeners syringe their houses freely; but it is doubtful whether that is the best plan, provided the air of the house is naturally damp. The effect of this simple application is very remarkable, quickly producing a visible change for the better in the appearance of the plants.

But *caution* must be used in the application. A piece of carbonate of ammonia as large as a shilling is sufficient for one charge in a stove 40 feet long; and it is indispensable that it should be volatilised by *rubbing it in water*, otherwise its causticity is too great, and leaves are burnt.

It is no doubt owing to the quantity of carbonate of ammonia which they evolve, that "dung-linings" have been found so much more conducive to healthy vegetation, than heating materials of any other kind. An experienced gardener gives the following directions for employing it in Cucumber pits, heated by hot water:—Use it twice a week, in the following manner. When you close the pit for the night, place a bit of the carbonate (pure), about the size of a large garden Pea, alternately back and front, under each light, on a small piece of glass, but dip the glass first in water, to wet it. The surface of the soil and interior of the pit should also be slightly syringed or otherwise moistened, in order that a quantity of moisture or vapour may be formed in the atmosphere at the time of the application; then shut up close for the night. The only caution required is to take care to procure *pure* carbonate of ammonia, and to use it only in a moist atmosphere, for it is much more caustic in dry than in moist air.

The effect of ammoniacal manure is to promote the growth of all the green parts, the colour of which becomes rapidly more intense under its influence. In excess it causes rankness, that is to say, it forces the vegetable tissue to form faster than it can consolidate, and in such a state plants are peculiarly subject to the attack of mildew. It is well known among farmers that rank corn is certain to mildew; rank potatoes suffer more from the same cause than such as form slowly; and the fact has been also observed in the case of the Vine disease. Whether the presence of nitrogen in excess is peculiarly favourable to the development of all kinds of fungi, which is probable, or whether they merely attack rank plants

because they are in a state of debility, is at present one of those uncertain subjects which are greatly in need of careful experimental investigation.

Putrid yeast is one of the most powerful of the nitrogenised manures; and it consists chiefly of fungi in a state of decay. The dark green colour assumed by the grass of fairy rings seems to show how large a quantity of nitrogenous matter Agarics possess. The property which such manure possesses of causing an excessive production of green parts is apparently exemplified by the tendency which Roses, manured with rank matter, have to form such green leaves in their centre as are represented at page 84.

The only natural FLUID which is of itself a food for plants is water; and there can be little doubt that, independently of its important offices as a solvent and a vehicle of other matters, it does directly contribute to Vegetable nutrition. It forms more than half the weight of fresh vegetables. When introduced into a plant it is decomposed and recomposed under the influence of vital force. Its energy is increased by an augmentation of temperature, to which may no doubt be ascribed, in part, the powerful effect of bottom-heat.

OF SOLUBLE SUBSTANCES those which need engage the attention of the gardener are chiefly, 1, *Lime;* 2, *Potash;* 3, *Soda;* 4, *Phosphoric acid;* and 5, *Sulphur.*

Lime.—When this substance is mixed with decaying matter, it hastens its decomposition, and renders it more easily assimilable by plants. This is its chief horticultural value, if regarded as a manure. (See p. 528.) In old cultivated land rich in humus it suddenly increases productiveness in a remarkable degree, increasing the properties of dormant animal or vegetable manure. Hence it has a most important effect in kitchen gardens. But limed land soon loses its productiveness unless manure is subsequently applied; and poor soils are soon run out by it. To some plants, such as many Conifers, it is injurious; to others it appears to be an indispensable article of food, such as Potatoes, Saintfoin, Barley, Beet-root, Peas, Clover, &c. It also expels ammonia from manure.

Combined with sulphuric acid it forms *Gypsum* (Sulphate of

Lime). This substance is considered to act in two ways:—directly, as food for plants, to which, being soluble in water, it supplies sulphur and lime; and, indirectly, by its action on the volatile carbonate of ammonia, which, wherever they meet, it "fixes." In this latter respect it acts in the soil on the ammonia of rain-water, as it does when applied to our dung-hills. Between sulphate of lime and carbonate of ammonia, when they meet in solution, a double action ensues; each of these salts is decomposed, and their elements unite in the forms of carbonate of lime and sulphate of ammonia: the advantage of the change arising from this latter salt of ammonia not being volatile as the carbonate is. The ammonia, the most important ingredient in manures, and the most fertilising element of rain-water, is thus retained for the benefit of the soil—safe from risk of loss by evaporation to the air again. Gypsum has been found to benefit green crops, as the Turnip, Cabbage, Potato, &c., and leguminous crops, as the Clovers, &c., more than grain crops. The results of numerous experiments have been published: much greater importance was at one time attached to the manure, especially on the Continent, than subsequent experience has justified, and accordingly its influence on a variety of plants has been tested in every possible way. Those who are curious on the subject will find a long and interesting chapter upon it in Boussingault's *Rural Economy*. Johnston's *Agricultural Chemistry*, too, is as instructive upon the theory and use of gypsum as it is upon all the other points regarding manures, soils, and plants which come within its province.

As to the rate at which this manure should be used, that of course is dependent upon the composition of the soil and of the plants for whose benefit it is to be applied: points so difficult and expensive to ascertain, that the common practice of sowing 4 or 5 cwt. per acre broadcast over the young plant in spring must in general be adopted. And when applied along with farm-yard manure, for the purpose of retaining the ammonia evolved during the fermentation of the mass, it must be used in the same rough way. It is cheap, and of itself useful as a fertiliser, independently of its indirect value as a fixer of ammonia. The theory of its action in this latter

respect would probably require in the case of rich manure nearly 1 cwt. of it to every ton—a quantity much greater than is *generally* used, though 20 cwt. and upwards per acre have been recommended by some writers.

M. Mène, however, says, that from numerous experiments he arrives at the following conclusions:—

1. That gypsum has by itself no fertilising power, and is useless as a manure if employed alone.

2. That gypsum is only useful when mixed with substances containing ammonia; in which case there is a double decomposition, and the ammonia is stored up for the use of the plants.

3. That for gypsum may be substituted any other salt which will fix ammonia, and render it not volatile at the ordinary temperature.

Gas-lime, or "Blue Billy," a substance poisonous to plants, has been occasionally employed incautiously as a manure, because it contains a large quantity of fœtid matters which have been thought to be beneficial. Manufacturers of fraudulent Guano employ it to scent their worthless compounds. Dr. Ure, speaking of this substance, says, it "contains and easily affords so much of the cyanic compounds that an eminent Parisian chemist has taken out a patent in France for manufacturing prussic acid and Prussian blue from that refuse. The only obstacle to the profitable working of this patent is the accompanying sulphurets, which discharge a great deal of sulphuretted hydrogen, along with the vapour of prussic and sulphocyanic acids; an aerial mixture of the most intense malignity to breathing animals." And he goes on to say that "that vile refuse should be buried many fathoms deep in some barren region, for when spread on the farmer's field, after discharging the above gaseous poison for some time, its sulphur gets oxygenated into sulphurous acid, two volatile products alike detrimental to plants." Without going into the chemistry of the subject, it is sufficiently obvious that fresh gas-lime is a dangerous agent, wholly unfit for use in confined places.

It must not, however, be therefore inferred that gas-lime is worthless or dangerous when properly applied. Its deleterious qualities disappear upon exposure to the air; sulphuretted hydrogen and sulphurets are speedily decomposed by contact with air and moisture; and any other pernicious matters which it may originally contain disappear, or enter into harmless combinations. Gas-lime is therefore, when old, a good calcareous manure, fit for the purposes in which lime is required—and something more; for the sulphur-compounds which it

contains themselves act as valuable manures, as soon as their intensity is destroyed by diffusion through masses of earth. Such at least appears to be the general opinion of practical gardeners.

Potash.—The ash which is left after wood or other vegetable matter is burnt, consists to a great extent of Potash, an alkali which seems to be indispensable to healthy vegetation. In uncleared countries the trees are burnt for the sake of this substance, which, after proper treatment, becomes the pearlash of the shops. It occurs in all plants, and with Soda and Lime is regarded by Liebig as specially destined to serve as a base for the organic acids of vegetation. In its caustic state it acts on decaying matter like Lime; as a manure it is only known in the form of some salt, of which the *carbonate*, *chloride*, and *nitrate* alone deserve mention. The carbonate is the common form in which it appears in wood-ashes. The periodical burnings of whole districts of heather, or bushes, or grass land, so common among savage nations, is for the purpose of manuring land with carbonate of potash, after which the scorched land is rapidly covered with a brilliant coat of green. The chloride exists *in soapboilers' refuse*, a good manure, whose efficacy is chiefly owing to this salt. Nitrate of potash (or *Saltpetre*) has a great influence on vegetation, promoting vigour, and rendering the tissues solid. It probably owes its action in part to the nitrogen it contains, and in part to the potash.

According to Persoz, potash contributes directly to the formation of flowers and fruit, and therefore he recommends it to be applied to the Vine in the following manner: "When it is wished that wood should be developed, the Vines must be placed in a trench and covered with 3 or 4 inches of earth, with which have been mixed, for every square yard of the surface of the trench, 8 lbs. of pulverised bone, 4 lbs. of pieces of skin, leather, horns, tanners' refuse, &c., and $1\frac{1}{2}$ lb. of gypsum. (Here ammonia is depended upon.)

"When the wood is sufficiently formed, which will be in a year or two, according to circumstances, the roots must be supplied with salts of potash, in order that the fruit may be produced. For this purpose it is necessary to spread over the trench, at a distance of 3 or 4 inches from the buried wood, for every square yard of surface, $5\frac{1}{2}$ lbs. of a mixture formed of 8 lbs. of silicate of potash, and $2\frac{3}{4}$ lbs. of double phosphate of potash and lime. The trench is then to be filled up, and the roots have as much potash as they will want for a long time. To

prevent, however, the exhaustion of the potash, it is as well to spread every year at the foot of the stools a certain quantity of the marc of grapes; this marc containing 2.5 per cent. of carbonate of potash, will restore annually a large proportion of the potash which may have disappeared from the trench."

Soapsuds have an undoubted value because of their potash, irrespective of the animal matter they contain. Upon Cabbages, Cauliflowers, and all the Brassicaceous race they produce an immediate and very advantageous effect. Potash constitutes the most valuable part of the ashes left after a plant is burnt, and adds powerfully to the fertilising effect of all composts to which they are added.

Vegetable or wood ashes are esteemed the very best manure by the Chinese. The weeds, which are separated from the land by the harrow, with what they otherwise are able to collect, are carefully burnt, and the ashes spread. The part of the field where this has been done is easily perceived by the most careless observer. Indeed, the vigour of the productions of those parts of their land where the ashes have been applied, is evident as long as the crop continues on the ground. The ashes of burnt vegetables are also mixed with a great variety of other matters in forming the compositions which are spread on the fields, or applied to individual plants. (*Hort. Trans.* v. 52.)

Soda is regarded by Liebig and others as a natural equivalent for potash, although it is present in much smaller quantities in the structure of plants. Weigman and Polsdorff found that the *Salsola Kali* which naturally grows in presence of a salt of soda (chloride of sodium) grew quite as well without soda if a salt of potash (chloride of potassium) were present; but that it would not grow in soil containing neither one nor the other. Hence, if this be so, we must infer that provided soil contains alkaline matter it is immaterial whether that matter be soda or potash; and also that the salts of soda have as good an effect on vegetation as those of potash. This point wants further examination. In the meanwhile it may suffice to say that the influence of the salts of soda is very analogous to that of salts of potash, as we believe we see in nitrate of soda and nitrate of potash. But in these instances it is not at all settled whether their good effect is owing to their nitrogen or their alkali.

Common salt (chloride of sodium) is very frequently used as a manure, and to plants naturally found on the sea-shore is indispensable. The magnificent Asparagus of St. Sebastian owes its excellence in some

measure to the beds being inundated with sea-water at *spring tides*, as we learn from Capt. Churchill, and we know that its influence is extremely beneficial to this crop whenever it is applied while the plants are making their growth.

The following testimony has been borne to its effect on Asparagus, in the *Gardeners' Chronicle:*—"I forked into worn-out beds some manure from an old Cucumber bed, levelled the surface, and completely covered the beds with fine salt, at least a $\frac{1}{4}$ of an inch in thickness, leaving it to be washed in by rains. The result was that every weed was killed, and the Asparagus has thriven in a remarkable degree, throwing up numerous heads of large size and of excellent quality." With equally good success another applied salt in summer at the rate of 2 lbs. per square yard. A third in the spring of 1843, which was cold and wet, manured his beds, 14 yards long and 1 wide, with salt at the rate of 2 lbs. to the yard. He adds that, notwithstanding the unfavourable season, his produce was greater and finer than ever he previously had it. In the following year the same plan was adopted, the spring being dry and frequently hot, and the produce was even greater and better in every respect than that of the previous year. So satisfied is another correspondent with the system of salting Asparagus beds, that he says:—"I have a bed 30 feet in length and 5 feet in width, on which I put 1 cwt. of salt about the middle of March for two years successively. The increase of crop, both in regard to size and number, is most extraordinary; I intend to continue 1 cwt. of salt for this bed every March." In like manner other writers used salt at the rate of from 1 lb. to $2\frac{1}{2}$ lbs. per square yard with the most striking advantage, applying it after cutting off the tops, and in spring in rainy weather. From these and numerous other instances it would appear that the beneficial effects of salt as a manure for Asparagus is fully established, provided it is applied at a proper period, which, in the majority of cases, has been when the plant was in a growing state. Mr. Bree, of Stowmarket, however, applied it with great advantage after dressing the beds in autumn, and again *early* in spring, using 1 lb. to a square yard. He argues that the salt has to be washed through a considerable depth of soil before it reaches the root, and when it does arrive there that its caustic character will have materially altered by dilution and chemical decomposition, and that it will do no harm then, but that it is injurious when applied to the delicate texture of the young shoots late in the spring. In the few cases in which salt has been said to be injurious, the beds have either been in bad condition as regards drainage, or it has been applied to beds newly formed, and therefore to plants with wounded roots, for such recently planted Asparagus must be considered to be, however carefully the plants may have been taken up. The same may be said of Sea Kale: about $1\frac{1}{2}$ lb. is used to the square yard. It is sometimes employed with advantage for Celery, but in that case

the dose should not be half so strong. Its general effects are not to force plants and give them a dark colour, like ammonia, but to consolidate their tissues, and to render them crisp as well as succulent. There is no sufficient proof of its preventing mildew, as has been often asserted; nor, on the other hand, is there any satisfactory disproof of that statement.

Glaubers salt (*sulphate of soda*) has been occasionally recommended, but it seems to have little value, and is hardly known in gardening. It may produce such good effect as belongs to it as much by its sulphur as its soda. According to Prof. Johnston it acts energetically on Potatoes, Rye, Peas, and Beans, "not upon the straw but upon their pods, increasing their number and enlarging their size." Dose, not less than 1 cwt. of the dry salt per acre, applied dissolved in water, or broadcast in wet weather.

Phosphoric Acid.—It has been long known that bones exercise a very powerful effect upon plants. If broken bones are used as the drainage of pots, roots soon find their way down to them and pierce them. Bone-dust has been used for years as a most valuable manure for Turnips when drilled in with the seed. The pastures of Cheshire, exhausted by the continual removal of grass by the animals that grazed upon them, recover their fertility when dressed with bones. To what is this owing? It was at first thought that it was the animal matter contained in them which gave the value. But boiled bones, and bones burnt to an ash, proved to be as efficacious as fresh bones. Then it was imagined that the lime contained in bones produced the effect; but lime used separately had no effect. Hence it became an irresistible conclusion that it was the phosphoric acid that in combination with lime (*phosphate of lime*) constitutes bones, which principally caused such unaccountable fertility. Hence arose the manufacture of superphosphate of lime, by Mr. Lawes, now so indispensable to cultivators. By mixing bones with sulphuric acid, their lime is in part seized upon by the acid, and converted into gypsum or sulphate of lime, and in part remains combined with the phosphoric acid, forming a superphosphate (or biphosphate) which readily dissolves in water, and is thus immediately presented to plants in a form in which it can be absorbed. Mere bones, on the contrary, part with their phosphoric acid slowly. The practical consequence is that mere bones continue to

produce an effect on land slowly but for a long time; while the effect of superphosphate, which acts immediately, soon disappears.

Superphosphate of lime is prepared by pouring over bones their own weight of sulphuric (or hydrochloric) acid, or half their weight; or by using their acids diluted with twice their weight of water, and when effervescence has ceased adding to the mass torrified sawdust, peat charcoal, bone-dust, or any other dry powder, which will reduce it to a state fit for drilling. Or it is mixed with a large quantity of water, and used in a liquid form. Or it may be prepared by placing $1\frac{3}{4}$ bushel of finely-ground bones in a tub, with half their weight of acid, diluted with four times the quantity of cold water; after some hours, a few bushels of fine mould and some coal-ashes should be added, so as to make the whole amount to 15 bushels of compost. This may be used in three days after its preparation, but would be better if kept longer. The mixture is to be applied at the rate of little more than 2 bushels per acre; when it successfully rivals 16 bushels of bones. Another way is the following. Take a large but shallow tub, about 18 inches deep (regulating the size according to the quantity required), spread the bones at the bottom of the tub, and add sufficient water barely to cover them, then pour in the acid, stirring the whole mass with a strong fork; an immediate effervescence takes place, and the bones will be sufficiently dissolved for use in 48 hours, or even less. To prepare the compost, mix half the quantity of peat or wood ashes—according to quantity of bones used, passing it, if necessary, through a coarse sieve—and afterwards adding as much dry mould as the drill requires. This plan is better than dissolving the bones in a heap of dry mould, because, without great care, the acid, when poured on the bones, is apt to escape into the mould, therefore it is better to add the water first; a tub is better than an iron vessel; sulphuric acid having a great affinity for metal will soon destroy it, but it has no effect upon wood.

If bones are to be used without preparation it is best to buy half-inch or inch bones, in order to avoid the frauds of dealers, who are apt to mix plaster of Paris and other worthless materials with bone-dust. It has also been suggested that it is advantageous to employ a preparation of bone, which, being very fine, requires no digesting with sulphuric or muriatic acid, and is both immediate and permanent in its effects: that is to say, the sawdust of a button factory; its effects are astonishing. The progress of the plant after the first shower of rain is so great that it has been employed by many gardeners with much advantage, among other things upon Pine plants, and the effects were wonderful. In 1842 Mr. Spencer, gardener at Bowood, used this bone-dust for Pelargoniums, and with good results. The roots that were emitted into

the soil containing the bone-dust, were as large as moderate-sized goose-quills; and the plants, in consequence of their having such strong and vigorous roots, grew to a size almost incredible. And not only were they large, but they were strong and vigorous enough to support their trusses without the aid of sticks, although many of the trusses consisted of twelve, thirteen, and fourteen flowers each. The plants had only a few sticks at the commencement of their growth, merely to keep the branches at regular distances from each other. The flowers were half as large again as usual. Some of these plants kept up a succession of flower from four to six months. A few that were "spotted" were put in soil containing the bone-dust, and in ten days they had put on so many young leaves as to completely hide the "spotted" ones. This dust was purchased cheap at a button factory in Bristol in 1839, but its value being soon ascertained, in 1842 the price was more than doubled. It is obvious that bone-ash only differs from button-dust in the want of animal matter.

The apparent effect of phosphates is to stimulate vegetation, and to promote the formation of roots. It is in this way more especially that they operate upon root crops, whose seeds form their radicles rapidly under the influence of phosphoric acid, and soon establish them securely in the ground beyond the reach of dryness. All plants whose ashes have been examined contain phosphates, which may therefore be regarded as universal vegetable food. "Alkaline and earthy phosphates form invariable constituents of the seed of all kinds of Grasses, of Beans, Peas, and Lentils."—*Liebig*. In Rhododendron ferrugineum they amount, according to Saussure, to 17·25 per cent. To have any value it is, however, indispensable that they should be soluble. Hence the insoluble phosphate of iron is useless to vegetation. This is to be remembered in estimating the worth of manure, for phosphates are now regarded as the most important ingredient in manure, with the single exception of ammoniacal salts. Hence when sewage water is deodorised by salts of iron, the resulting phosphate being insoluble, the liquid loses much of its value.

Sulphur.—"Plants contain, either deposited in their roots or seeds or dissolved in their juices, variable quantities of compounds containing sulphur. In these nitrogen is an invariable constituent. Two of the compounds containing sulphur exist in the seeds of cereal plants, and in those of leguminous

vegetables, such as Peas, Beans, and Lentils. A third is always present in the juices of all plants; and it is found in the greatest abundance in the juices of those which we use for the purposes of the table."—*Liebig.*

This sulphur is obtained from the sulphates contained in soil. Hence the value of such substances as sulphate of lime (gypsum), of sulphate of ammonia formed when sulphuric acid is brought into contact with carbonate of ammonia in dung-hills, and of the fœtid gas called sulphuretted hydrogen, which is formed abundantly in the decomposition of animal matter.

Sulphur alone has been used to advantage as a manure. Not being soluble in water, it cannot pass as such into the plants; still, if it is well pulverised, it will be converted (by attracting the oxygen of the air) into sulphuric acid, which will then unite with any bases of the soil into a sulphuric salt. This process will most probably easiest take place when the soil contains much carbonate of lime, as the lime disposes (by its great affinity for sulphuric acid) the sulphur to unite quicker with the oxygen of the air. It is, however, very doubtful if sulphur could be used as a manure on a large scale. In addition to this it is asserted that experiments have proved the utility of sulphurets (combinations of sulphur with the metals of lime, soda, or potash) as manuring substances. It is also stated that they destroy worms and insects, most probably by developing sulphuretted hydrogen gas by their decomposition. We have seen before, that gypsum and ashes often contain sulphuret of calcium and sulphuret of potassium. Further experiments have to prove whether these substances can ever be usefully employed in agriculture on a large scale. I have often used potashes, containing much sulphuret of calcium, as a manure, but the effect seemed neither good nor bad.—*Sprengel.*

The great objection to manures containing sulphuretted hydrogen is its intolerable fœtor. "The offensive exhalations produced by putrefying matters arise," says Schattenmann, "principally from the flying off of carbonate of ammonia and sulphuretted hydrogen gas: but if a solution of sulphate of iron is thrown among such matters, a double decomposition immediately takes place; the sulphuric acid of the sulphate of iron combines with the ammonia, and converts it into a fixed salt; the iron combines with the sulphur, and forms a sulphuret of iron. The unpleasant smell of ammoniacal vapour and of sulphuretted hydrogen disappears immediately, and the putrefying matter that is acted on retains nothing more than a feeble odour, which is not in the slightest degree disagreeable." The objection to this mode of disinfecting manure is that the phosphoric acid of manure is likely to be converted into an iron phosphate and thus rendered

useless, and that the free sulphuric acid attacks the straw and renders it less capable of decay.

It thus appears that the important substances which are required to form an artificial food for plants are 1, Carbonic acid; 2, Nitrogenous compounds; 3, Water; 4, Lime; 5, Potash; 6, Soda; 7, Phosphoric acid; and 8, Sulphur. For practical purposes other matters may be neglected.

We are not, indeed, warranted in regarding the presence of iron, copper, or other substances, in plants, in minute quantities, as altogether accidental and unimportant; for I do not know what warrant we have for saying that any of the constant phenomena of nature, however minute they may seem to be, are accidental. It is certain, that, where mineral substances occur abundantly in plants, they are part and parcel of their nature, just as much as iron and phosphate of lime are of our own bodies; and we must no more suppose that grasses can dispense with silica in their food, or marine plants with common salt, than that we ourselves could dispense with vegetable and animal food. Copper occurs in Coffee, Wheat, and many other plants (it is believed in the state of a phosphate); iron, as a peroxide, in Tobacco. John, in his experiments upon these matters, found that the Ramalina fraxinea and Borrera ciliaris, two lichens, contained a great quantity of the last metal, although he could not find a trace of it in the Fir-tree, on the topmost branches of which the lichens grew. We cannot suppose that such things are the result of accident, and that it is unimportant to the plants containing minerals thus constantly, whether such substances are present in their soil or not; but we may be permitted to believe that all cultivated land contains as much as plants require, and that they need not be supplied artificially.

In order to ascertain which of these is most important to a given plant, recourse has been had to the analysis of the ashes of plants, and we have a large quantity of evidence upon the subject; the value of that evidence has, however, been much disputed. An eminent chemist speaks with great disrespect of the laborious analyses of Sprengel, and those of others have been objected to on various grounds. There are, however, certain great facts which are admitted. All Grasses and Horsetails must have silica in abundance; lime is indispensable to the Vine, to Peas, Clover, Saintfoin, and Tobacco; soda-salts to marine plants; alkaline matter, especially potash-salts, to land-plants, and especially to Conifers and other trees; phos-

phates to plants yielding flour, the Jerusalem Artichoke, Cabbages, Turnips, &c. On the other hand, lime is injurious to Heaths; manures containing much nitrogen to Conifers and stone-fruits, and so on.

The progress of Chemistry has not, however, been able to furnish the gardener with any considerable amount of such detailed information as he can use; the application of soils and manures to plants remains for the most part within the routine of *art*, and the gardener is still obliged to trust to his dunghill for the elements of fertility. The author is, therefore, content to leave the refinements of manuring within the province of the chemist, and to point out the peculiar properties of the manures in common use.

Farm-yard Manure, when well made, is probably the best of all, because of the great variety of substances which it contains. It owes its blackness to vegetable mould, its peculiar odour to ammonia and sulphuretted hydrogen; it acts mechanically by the undecayed straws of which it consists, and it contains within it all the alkaline and earthy salts and phosphates that were locked up in the tissues of the various plants of which it is composed. When wood-ashes, the ashes of coal, the highly fertilising "house slops" of all kinds, consisting of urine, soap-suds, grease, are carefully added, it becomes greatly improved; and if decaying animal matter is superadded, its nitrogenous products are so increased as to render it necessary to weaken its force by mixing it with earth. For garden purposes such manure is, however, inappropriate, except in the case of kitchen garden crops like Cabbages, &c., Celery, Asparagus, Sea Kale, Lettuces, and the like. To fruit-trees it is injurious. When otherwise used in gardens it requires to be reduced to the condition of mere mould, when its nitrogenous constituents shall have been much dispersed.

According to Richardson's analysis, 10,000 parts of farm-yard dung contain 322 potash, 273 soda, 34 lime, 711 phosphate of lime, 226 phosphate of magnesia. Boussingault found only 2 per cent. of nitrogen in what he examined in the dry state; and Richardson none at all: from which we must conclude, either that the substance examined was badly made, or that the analyses are imperfect.

Gardeners may substitute advantageously for farm-yard manure the following *compost*. In a hole or dry ditch deposit during the year all the leaves, straws, vegetable refuse, that can be collected; over these pour daily the "house slops." If offensive smell arises stop it by Peat, or Peat charcoal, or any substance which will advantageously deodorise putrescent matter. Should gas-water be obtainable, an occasional drench with this will be advantageous. To the whole add from time to time all that remains after heaps of wood and cuttings have been burnt. The "mixen" will contain all the eight substances by which plants are artificially fed.

Guano, the deposit of sea-birds on dry islands in the Pacific, is the richest of all natural manures. It will contain, if of good quality, in the best possible state for application to land, about 17 per cent. of ammonia, and 25 per cent. of phosphate of lime, upon which alone its value depends. But it is enormously adulterated.

There is perhaps no garden crop which this does not suit, if not applied too much at a time; the liquid form is preferred by gardeners. It would be a most valuable ingredient in the *compost* just mentioned.

Night Soil.—This is a material of great energy, and was probably one of the first substances employed by man when he began to discover the value of manure. It forms the principal resource of the Chinese, whose agriculture may be assumed, owing to the unchanging habits of that people, still to bear a strong resemblance to its primæval condition. In its ordinary state this is largely composed of water, and is rich in phosphates and ammoniacal compounds; but it runs rapidly into a state of fermentation, evolving nauseous gases, and becoming too offensive for employment in its natural state. Moreover, if so used, it proves absolutely poisonous to vegetation unless it is largely mixed with other substances, or diluted with water. The most advantageous and economical manner of employing it is to add powdered charcoal, peat, charred sawdust, or even mere clay, daily, to the receptacles in which it is deposited, by which means its peculiar gases are detained, and its offensive odour destroyed. Lime should never be mixed with it, if

its value as a manure is to be preserved. Kitchen garden crops, requiring strong manure, such as Asparagus, are those to which it is most suitable. Trees, shrubs, and fruit-trees are the least fit to receive its influence.

Various deodorised preparations of this substance are in the market, under the names of *Poudrette*, animalised black, Poitevin's manure, Dutch or Flemish manure, &c.; but such preparations are frequently almost inert, in consequence of unskilful management on the part of the makers. No state of night-soil is so active as that in which it is mixed with fine charcoal till its offensive odour is destroyed. Another valuable preparation consists in mixing it with twice its weight of dry bog earth, and the same weight of gypsum in fine powder; but in this, as in all other cases, the urine belonging to it should never be allowed to run to waste.

Pigeons' Dung approaches nearly to guano in its effects. In Persia dove-cotes are kept in the midst of the plains for the purpose of securing this valuable dejection. The Persians use it, as the Peruvians use guano, by mixing a small quantity in the soil in which their Melons and other crops are planted. Wherever it has been tried in this country, it has been found of the greatest energy. The only danger in using it is that it may be too strong and burn. The Belgians employ it as a top-dressing for flax. When fresh it contains about 23 per cent. of ammoniacal and alkaline salts, besides a considerable quantity of phosphoric acid. It deteriorates by keeping.

"A plant of Heath (Erica australis, I believe) was placed under my care in the spring of 1823, with a request that I would treat it in any way I wished. It was then about eight inches high, and growing in a small quantity of peat earth and sand; and in that it continued to grow with very little increase of size till the following spring. From that period it was regularly supplied with water, which, though clear, was considerably tinged with an infusion of pigeons'-dung. I was apprehensive this kind of food would prove fatal to it; but far from this being the result, the plant grew with excessive health and vigour, emitting very numerous branches, eight of which exceeded eighteen inches each in length. It was then taken away by the owner of it, and I have not since seen or heard of it, but it left me in a state of luxuriant health."—*Knight in Hort. Trans.*, vii. 183.

The *Blood of Animals*, when dried, yields about 17 per cent. of ammonia, but no phosphoric acid. Mr. Way suggests that

it should be mixed with mineral superphosphate of lime. It has been much praised as a manure for Orange-trees and the like.

Hair, horns, shavings, and *refuse matter* of a similar nature, are very like blood in their action, as they are in their composition, each containing about 17 per cent. of nitrogen. They, however, decompose much more slowly, and may be used advantageously wherever ammonia is to be formed slowly but permanently. Vine borders are improved by them, and to Hops they seem to be of specific value.

Malt-dust, the dried radicles of barley, is very rich in nitrogen. It is employed as a top-dressing for lawns, or to promote the formation of roots by sifting over ground about to be turfed. Its effects are powerful but transient.

Oilcake, in powder, has also a highly energetic though transitory action. Its great value consists in giving an impulse to vegetation in the early stages.

Sawdust, Spent Tan, and similar refuse woody materials, have no value in gardening until they have been rotted down or charred; on the contrary, they are apt to injure the soil to which they are applied. This has, however, been denied.

> "The following experiment with Strawberries in tan I saw made near Edinburgh. The soil was very light, and appeared unfit for their growth, yet finer fruit or of better flavour I have seldom seen. This was entirely owing to a covering of old tanner's bark, about an inch thick, being applied between the rows. The bark not only kept the ground moist and the fruit clean, but it is the material of all others in which this plant most delights. Many persons may have remarked how almost all plants, but particularly the Strawberry, will root into the old tan of a bed in which they have been forced, and yet because they know new tan will kill weeds, they do not think it valuable as a manure. In the same garden were beds of Strawberries which had not been covered, but after growing, and flowering well, these bore no fruit worth gathering (a very common thing if the soil is too light); others were almost burnt up, whilst those to which the tan had been applied were luxuriant, and the ground was covered with fine runners fit to plant out, though the fruit was just in perfection—an uncommon circumstance near Edinburgh."—*I. R. Pearson, Chilwell.*

Burnt Clay.—Why burnt clay should be better than that sort of soil in its ordinary condition, is sufficiently obvious. Its

texture is changed. In its natural state it is so adhesive, that air cannot get into it, nor water out of it. It also offers great mechanical opposition to the passage of roots through its viscid mass, and hence it is exclusively inhabited by a coarse and worthless vegetation. Burning changes all this; the particles of clay lose their adhesiveness, and this alone gives a new character to the soil, which offers freedom to the entrance of air and exit of water, and which crumbles readily away beneath the advancing roots of a soft and succulent race of plants. Such changes are in themselves most important; but this is not all the difference between burnt and unburnt clay. The roots of plants, which were before unable to decay, are reduced by fire to their saline constituents, and so enrich the land. And, moreover, the burnt particles of clay acquire the power of absorbing ammonia from the air, and holding it within their pores till showers fall and wash it into the land, where it immediately acts as a nourishing food to the crops.

Mr. W. Paul, of Cheshunt, says, "It has been the custom here for some years, in spring, when the operations of pruning, &c. are ended, instead of suffering the rough branches to lie about, presenting an untidy appearance, to collect them in a heap, and build a wall of turf round them in a semicircular form, about three feet high. They are then set fire to, and when about half burnt down, such weeds and other rubbish as collect in every garden, and will not readily decompose, are thrown on the top, and earth is gradually cast up as the fire breaks through. During the first two or three days no ordinary care is requisite to keep the pile on fire, but after this, if the fire is not allowed to break through and thus expend itself, it will certainly spread through the whole heap, and almost any amount of soil may be burnt by still adding to the top. The soil we burn is the stiffest loam that can be found within our limits, and is rather of a clayey nature; also turf from the sides of ditches and ponds, in itself naturally sour and full of rank weeds. The clay thus burnt has been found beneficial in every instance. In black garden mould, where Peach-trees were disposed to sucker and canker, despite of animal manures and drainage, two or three annual dressings of burnt earth appear so to have altered the soil that they now grow clean, vigorous, and healthy, are free from suckers, and produce roots completely matted with fibre. The like success has attended its application to other fruit-trees. During the summer of 1842, six beds of Tea-scented Roses, growing in an alluvial loam (the adjacent fields are of the same soil, and grow large crops of

Wheat and Potatoes, but the particles of soil run together after rain, and present a smooth cemented surface) were manured with the following substances, viz., 1, bone-dust; 2, burnt earth; 3, nitrate of soda; 4, guano; 5, pigeon-dung; and 6, decomposed stable manure. The guano produced the earliest visible effects, causing a vigorous growth, which continued through the season; the flowers, however, were not so abundant, and the shoots did not ripen well, and were consequently much cut with the frost. The bed manured with burnt earth next forced itself into notice; the plants kept up a steadier rate of growth, producing abundance of clean, well-formed blossoms; the wood ripened well, and sustained no injury during winter. The results of the other manures were not remarkable—acting as gentle stimulants, the nitrate of soda and bone-dust least visibly so—although they were applied in the quantities usually recommended by the vendors. From the fact of the beds of Roses being all planted at the same date, and their progress being carefully watched, I would suggest the application of burnt earth as an excellent manure for Roses in adhesive soils, as well as for fruit-trees where disposed to canker. Whether it acted by furthering drainage, or by opening the soil to the fertilising influences of the atmosphere, or by fixing the ammonia conveyed to the soil by rain, I do not pretend to say, but its value is sufficiently apparent. I believe it is considered that the vegetable matter contained in soils is destroyed by the act of burning; and I do not think the remains of the materials used in combustion could exercise any extended influence, as the quantity compared with the earth burned is so small, and the earth comes from the heap burnt red and hard, and a great portion quite free from the substances used in ignition." This is confirmed by Mr. Rivers, another eminent Rose-grower, and by Sir Oswald Mosley, who makes the following remarks:—"I have had for some time past several of these burning heaps in the environs of my garden, which produce us in succession a very valuable manure: they are easily kept in a state of combustion, and all the care they require is, to cover and surround them occasionally with fresh clay or marl, that they may not burst out into an open flame. My gardener sowed two beds of Onion-seeds of the Globe, James's Keeping, and Strasburg sorts, mixed together, about the 10th of March last, with one pound of seed to each bed. The beds were each of them eighteen yards by twelve yards, and one of them was manured with good stable dung; the other by this mixture of burnt clay and vegetable ashes. The produce of the first did not exceed five bushels of an inferior size, the greater part having been destroyed by the larva of the Onion-fly, whilst that of the latter was twenty bushels of Onions, as large as those imported from Portugal. Another remarkable circumstance is, that the former have not kept well; but the latter are as sound as possible, not a single bulb in the strings showing the least appearance of decay. The

same burnt mixture has been applied with equal success in my fruit-garden. I had observed a great decrease in my crop of Apricots for several years past, and upon a careful investigation as to the cause, my gardener and I agreed that it must be owing to the tenacity of the border; we therefore had the old soil removed, and a quantity of this burnt mixture with a little fresh loam substituted for it. My gardener planted the border so renewed with runners of Keen's Seedlings in rows; they became strong plants by June, when they flowered and produced an abundant crop, and all my Apricot-trees were covered during the summer with well-ripened fruit. I am so fully persuaded of the excellence of this kind of manure, that I intend to adopt it generally on my farm. It will there have a double advantage; for I shall be enabled to save the farm-yard dung for composts, and I shall have the gratification of seeing my hedges neatly trimmed and my ditches well cleared out. Our stiff soils will be also rendered more friable, and will not suffer as they now do from the retention of wet on the surface."

Green Manure is, perhaps, for many places, the best of all, inasmuch as it consists of young highly nitrogenous matter, ready to pass immediately into fermentation and decomposition, and to restore to the earth all that it has abstracted, as soon as it is buried. Moreover, if the plants used for this purpose are tap-rooted, they bring up from the depth of the soil a large quantity of alkaline and earthy matter, and leave it near the surface, within reach of the roots of plants with less power of penetration.

It has been said that by this method the most infertile soils may be rapidly rendered productive. Lupines, Borage, Rape, Spurry, or in fact any crop that forms large leaves and grows fast, being sown *close*, and dug in as soon as *they are ready to come into flower*, rapidly enrich land poor in organic matter, or exhausted by repeated cropping, and render it fit for renewed cultivation. If crops suited to the climate are selected for this purpose, two or three crops will succeed each other in the same year, and each contribute their quota to the soil. It is also said that, owing to the increased temperature of soil thus treated, owing to the fermentation of the green matter buried, each successive crop grows faster and adds more than that which preceded it. In this way barren sands are said to have been rendered fertile, and exhausted kitchen gardens are

known to have been speedily renovated. It is no objection to this mode of treatment, which is of great antiquity, to say that it has only a temporary value, because the same must be said of any other way of manuring.

The following experiments attest the value of the practice :—

"I received from a neighbouring farmer a field naturally barren, and so much exhausted by ill management, that the two preceding crops had not returned a quantity of corn equal to that which had been sowed upon it. An adjoining plantation afforded me a large quantity of Fern, which I proposed to employ as manure for a crop of Turnips. This was cut between the 10th and 20th of June; but as the small cotyledons of the Turnip-seed afford little to feed the young plant, and as the soil, owing to its extreme poverty, could not yield much nutriment, I thought it necessary to place the Fern a few days in a heap, to ferment sufficiently to destroy life in it, and to produce an exudation of its juices; and it was then committed, in rows, to the soil, and the Turnip-seed deposited with a drilling machine over it. Some adjoining rows were manured with the black vegetable mould obtained from the site of an old wood-pile, mixed with the slender branches of trees in every stage of decomposition, the quantity placed in each row appearing to me to exceed more than four times the amount of the vegetable mould, which the green Fern, if equally decomposed, would have yielded. The crop succeeded in both cases, but the plants upon the green Fern grew with greatly more rapidity than the others, and even than those which had been manured with the produce of my fold and stable-yard, and were distinguishable in the autumn from the plants in every other part of the field by the deeper shade of their foliage." —*Knight, in Hort. Trans.*, i. 250.

A writer in a Bavarian weekly journal recommends sowing Borage, and when it is full grown ploughing it down. The good effects of this plant as a green manure he has proved by long experience. What renders it preferable to most other plants for this purpose is the great quantity of soda and other salts which it contains. It may be sown in April, and ploughed down in August in time to be followed by Wheat. (*Gardeners' Magazine*, i. 200.)

"I had been engaged in the year 1810 in some experiments from which I hoped to obtain new varieties of the Plum, but only one of the blossoms upon which I had operated escaped the excessive severity of the frost in the spring. The seed which this afforded, having been preserved in mould during the winter, was in March placed in a small garden-pot, which was nearly filled with the living leaves and roots of grasses, mixed with a small quantity of earth, and this was sufficiently covered with a layer of mould, which contained the roots only of grasses, to prevent in a great measure the growth of the plants which

were buried. The pot, which contained about one-sixteenth of a square foot of mould and living vegetable matter, was placed under glass, but without artificial heat, and the plant appeared above the soil in the end of April. It was three times during the summer removed into a larger pot, and each time supplied with the same matter to feed upon; and in the end of October its roots occupied about the space of one-third of a square foot, its height above the surface of the mould being then nine feet seven inches. In the beginning of June a small piece of ground was planted with Potatoes of an early variety, and in some rows green Fern, and in others Nettles, were employed instead of other manures; and, subsequently, as the early Potatoes were taken up for use, their tops were buried in rows in the same manner, and Potatoes of the preceding year were placed upon them and covered in the usual way. The days being then long, the ground warm, and the decomposing green leaves and stems affording abundant moisture, the plants acquired their full growth in an unusually short time, and afforded an abundant produce, and the remaining part of the summer proved more than sufficient to mature Potatoes of an early variety."—*Knight in Hort. Trans.*, i. 249.

Provided manure is of a permanent character, it does not very much matter at what time it is administered, because, if it does not act at first, it will sooner or later; but when it is of such a nature as to be easily dissipated, like malt-dust, or soot, or putrid yeast, a knowledge of the proper season becomes extremely necessary. Plants will not receive the influence of manure so readily at any season as when they are in the most rapid and steady growth; because at that time the absorbing force of their roots, and their vital energies, are all greatest. It is for this reason that a top-dressing is almost useless to a lawn at midsummer, but better in the spring, and best of all in October. If applied at midsummer, the ground is dry, the herbage closely shorn, and the vegetation extremely languid, partly in consequence of the constant operation of the mower, and partly because our summertide is the winter of herbage grasses, which only flourish in the cool and damp seasons of the year. When a top-dressing is applied in the spring, the lawn profits by it so long as it continues to grow vigorously; but the quick approach of summer daily interferes with the force of this kind of vegetation, and diminishes the effects of the manure. On the contrary, if October is the season chosen for the operation, the grasses are then beginning to grow

steadily, the operations of the mower are, or should be, suspended, and there are seven clear months at least during which the effects of the manure continue to be felt.

It may be indifferent at what season such manures as bones, and other kinds of matter which decompose very slowly, are employed; yet there can be no doubt that upon every known principle they also should be given at a time when vegetation is most active, or about to become so; hence the every-day practice of digging manure into the borders of a garden in spring, or shortly before an annual crop is about to be committed to the soil.

As to the manner of applying manure, it must be obvious that it can be of no use unless it is in contact with the absorbing parts of the roots; now those parts are the young fibres and spongioles, as has been already stated, and, when plants have arrived at any considerable size, the roots form the radii of a circle whose circumference is the principal line of absorption. This being so, if a plant has arrived at the state of a bush or tree, it is useless to apply manure to the base of the stem, because that is precisely where the power of absorption is the weakest, if it exists at all; and, as the circle formed by the roots is generally greater than that of the branches, the proper manner of applying manure is, to introduce it into the ground at a distance from the stem about equal to the radius formed by the branches. And yet, although this is so evidently right, I have seen a gardener, who ought to have known much better, sedulously administering liquid manure, by pouring it into the soil at the base of the stem; which is much the same thing as if an attempt were made to feed a man through the soles of his feet.

Manure may be applied in either a solid or liquid form. The former gradually parts with its fertilising properties; the latter communicates them instantly. When solid manure is used a certain, and perhaps large, portion of what is volatile is lost; of liquid manure the whole may be absorbed, or safely deposited within reach of roots, if precautions are taken against its running to waste. The application of solid manure is costly, in consequence of the labour which attends it: liquid

manure, on the other hand, if distributed by either superficial or subterranean channels, reaches plants at a comparative small cost. On the other hand solid manure acts not merely in its capacity of nutriment, but as an effectual means of counteracting the natural tendency of soil to consolidation, a tendency which liquids, repeatedly applied, augment. It "keeps the land open." Moreover, it parts with its nutrient qualities slowly, giving plants time to absorb them, and not overfeeding them at one time, while at another it starves them. The last-mentioned advantage on the part of solid manure is, however, less than it seems to be, for in consequence of the facility of its application, liquid manuring may be repeated over and over again without difficulty or material expense. Upon the whole it seems to be now generally admitted that when circumstances favour its application on a great scale it is preferable to solid manure; and that in the finer operations of gardening its superiority, under all circumstances, is incontestable.

Cultivators who know nothing of manure except from the action of the solid, and sometimes not very useful, materials produced in farmyards, cannot believe that half-a-dozen crops of Grass per annum are possible, each heavier than the preceding. Nevertheless, such crops are attained by skilful men, and will one day be common. Liquid manure works the wonder; it operates like the overflow of the Nile or the Indus. Where such periodical floods occur, they soak the land within their reach with the rich ingredients dissolved or suspended in their waters, and this, combined with the high temperature of the land itself, forces on vegetation at a rate unknown with us, except where liquid manure is expeditiously and abundantly administered. That being done we have the heavy and frequent crops of Messrs. Huxtable, Dickinson, Kennedy, Telfer and others. Grass begins to grow; it is deluged with liquid manure; on goes the crop, exhausting the land, but rapidly forming an abundant swathe; it is cut. Instantly afterwards the exhaustion is made good by a new torrent of liquid manure, which restores fertility and something more; up springs the crop again; again it yields itself to the scythe, but more abundantly than ever. The process of liquid manuring continues to be repeated with the same results as long as the season permits of growth; and it may be repeated for ever. What is true of a Grass field is equally true of a Cabbage garden, of Celery, Peas, Lettuces, Asparagus, and all kinds of garden stuff, so far as the power of liquid manure in causing exuberant growth is concerned.

In delicate horticultural operations, liquid manure, prepared by steeping dung or other fertilising matter in water, and drawing off the latter when clear, is most generally now employed, and is undoubtedly the best form in which it can be administered, in consequence of its concentration, the facility of its administration in any quantity, and its containing nothing but soluble matter. It was first used by Knight, who not only applied it with much advantage to fruit-trees, but also to Heaths and other flowers; and it is, with the exception of bone-dust, the form of manure best adapted to all plants in pots.

Among the many receipts for making liquid manure, the following are the best:—One gardener recommends, as "a composition which is within everybody's reach, and which has benefited every plant to which he has applied it,—soot, dissolved, or rather mixed, with rain-water, in the proportion of one tablespoonful of soot to a quart of water for plants in pots, but for Asparagus, Peas, &c., six quarts of soot to a hogshead of water. It must never be applied to plants in a state of rest. It succeeds admirably with bulbs." Another great grower, though writing anonymously, says, "Liquid manure is within the reach of every small gardener who possesses a supply of water and a common watering-pot, or an old barrel. Idle boys are plentiful enough, and will gladly pick off a common a bushel of sheep's dung for a shilling. If this cannot be procured, guano is excellent; 1 lb. of either to six gallons of water may be applied to the roots of most plants to much advantage. Annuals, Pelargoniums, Verbenas, Calceolarias, and similar ornamental plants are astonishingly improved by a watering twice a-week, especially in dry weather, when these things suffer, and flower in consequence weakly. The culinary department will also repay the cultivator for similar attention. Cauliflowers, Celery, Cabbage, &c., can scarcely have too much liquid manure. Twice every week will do immense service. There is no better prevention of mildew on Peas than this—the crop will be greatly increased by its application, and the quality infinitely raised." Mr. Errington suggests some kinds of urine, combined with good guano in solution, for plants in pots. "I have used this mixture constantly for the last two years, and its effects on many plants is quite astonishing. Sometimes I use that from the cow-house, sometimes horse refuse; and I am not prepared at present to point out any perceptible difference. I have a reservoir in which these fluids lay to ferment a fortnight; they are then transferred to another, when I add highly clarified guano-water, made by dissolving the best Peruvian guano, in clear *tepid* water, after the rate of four ounces to every gallon of the above fluids. My Camellias surprise every one

who sees them; they are so dark a green that they are almost black, whilst the texture of the leaves is like that of the Hoya carnosa, and the buds, with which they are covered thoroughly, are of immense size. Fibrous masses of soil, in conjunction with thorough drainage, coupled with the constant use of weak and highly clarified liquid manure, constitutes, in my opinion, the *ne plus ultra* of plant cultivation, as far as the root management is concerned."

In order that the full effects of liquid manure should be felt, without injury, it is indispensable,—1, that it should be weak, and frequently applied; 2, that it should be perfectly clear; 3, that it should be administered when plants are in full growth. If strong it is apt to produce great injury, because of the facility with which it is absorbed, beyond the decomposing and assimilating power of plants. If turbid it carries with it, in suspension, a large quantity of very fine sedimentary matter, which fills up the interstices of the soil, or, deposited upon the roots themselves, greatly impedes their power of absorption. If applied when plants are torpid it either acts as in the case of being over strong, or it actually corrodes the tissues.

"Sir Joseph Paxton collects at Chatsworth the manure water from water-closets, horse-dung linings, and various other sources, into large covered tanks; the waste, also, from a small bath is emptied into one of these, by which means the solution becomes very thin. The liquid so collected passes almost immediately into a state of incipient or partial decomposition, and thus becomes fit for the food of vegetation; when drawn off for use, *it is always greatly diluted with water*, and *never supplied except when the plants are in a state of activity and growth;* otherwise he considers the effects would in many cases be prejudicial, rather than otherwise. It is used by him liberally to Vine-borders, Peach-trees, Melons, Cucumbers, Pines, and other fruits, with the most powerful and satisfactory results; in fact, the use of plant food in a liquid state, if properly prepared and administered, supersedes in a great degree the necessity for manure in a solid form; and the produce in favour of the liquid greatly preponderates, being both larger in quantity and weight, richer in colour, and superior in flavour. These advantages, however, could not be secured with certainty, unless the solution were so prepared as to suit the habits and requirements of the various plants to which it is supplied. This preparation is of two kinds:—First, by *diluting the liquid sufficiently with water* to prevent the spongioles of roots becoming glutted with too great a supply of food; and, secondly, rendering it of a proper temperature by the addition of hot water. Pines require the liquid at about a heat of 80° Fahr., and

other plants in proportion; fruit-trees, and other open-air products, however, do not necessarily require the addition of hot water to the same extent as in-door produce, but are, notwithstanding, much benefited by receiving it in a moderately warm state. Wherever a steam-engine is employed, Sir Joseph Paxton's practice of artificially warming the liquid manure might be easily adopted, by allowing some of the waste steam to blow through the tank or pipe. Experience has, however, amply shown that, for ordinary crops, sewerage in its usual state is the most valuable manure that has yet been introduced. By attention chiefly to the proper administration of liquid food, and other suitable appliances, the Pine-apple, a plant formerly considered of so slow a growth as to require three years before it could produce full-sized fruit, has by Sir Joseph been so hastened in its growth as to yield, within an average of fifteen months, a far greater supply of finer fruit than was formerly produced by three years' expense and labour. From every day's experience, an instance or two out of a multitude might be cited by way of illustrating that even a much shorter period than fifteen months is not unfrequently sufficient to accomplish all that could be desired. An ordinary sucker of a Providence Pine was detached from the old stock during the month of March, and was planted out in a prepared bed of soil in a pit, and in the following August it produced a ripe well-grown fruit, weighing 8 lbs. Two suckers also of a Cayenne Pine were separated and planted out in April, and in the following September one of them produced a fruit weighing $7\frac{1}{4}$ lbs., and the other one 8 lbs. A large pit of Cayenne suckers of various sizes were planted out in a pit last spring, and in the autumn the fruit, when ripened, gave an average of one pound in weight for every month the plants had grown. These were not isolated or extraordinary instances of early production, but the common and natural result of this system of culture, which stimulates to extraordinary growth, and the most perfect developement. The effects of liquid manure, when applied to the roots of Vines in pots, and on rafters, and to Cucumbers and Melons, are equally apparent; the leaves assume a rich deep colour, become large and spreading, the growth is rapid and healthy, and the produce is invariably fine, plump, and becomes quickly matured."—*Board of Health Report.*

Let the manure be extremely weak; it owes its value to matters that may be applied with considerable latitude; for they are not absolute poisons, like arsenic and corrosive sublimate, but only become dangerous when in a state of concentration. Gas-water illustrates this; pour it over a plant in the caustic state in which it comes from gas-works, and it takes off every leaf, if nothing worse ensues. Mix it with half-water—still it burns; double the quantity once more—it may still burn, or discolour foliage somewhat. But add a tumbler of gas-water to a bucketful of pure water, no injury whatever ensues;

add two tumblers full, and still the effect is salubrious, not injurious. Hence it appears to be immaterial whether the proportion is the hundredth or the two hundredth of the fertilising material. Manuring is, in fact, a rude operation, in which considerable latitude is allowable. The danger of error lies on the side of strength, not of weakness. To use liquid manure very weak and very often is, in fact, to imitate nature, than whom we cannot take a safer guide. This is shown by the carbonate of ammonia carried to plants in rain, which is not understood to contain, under ordinary circumstances, more than one grain of ammonia in 1 lb. of water; so that in order to form a liquid manure of the strength of rain-water, 1 lb. of carbonate of ammonia would have to be diluted with about 7000 lbs. weight of water, or more than three tons. Complaints which have been made against guano-water and the like are unquestionably referable to their having been used too strong.

Let such manure be applied only when plants are in a growing state. In addition to Sir Joseph Paxton's evidence, and to the general notoriety of this rule, may be usefully added a statement made by Mr. Mitchell, Lord Ellesmere's gardener, and quoted by the Board of Health. This experienced cultivator says "That he has never seen any manure produce so good a crop of Strawberries as the liquid (*i. e.* town or sewer manure) has this year done at the Worsley Hall gardens. Manure," he adds, "often causes a crop of Strawberries to be lost, by forcing the growth of leaves. Liquid may be applied *just when the plants are forming their flower-buds*, and the strength of the manure is spent in producing fruit, not leaves. When the plants were bearing, it could be seen to a plant how far the irrigation had extended."

It must be borne in mind—1, that *liquid manure is an agent ready for immediate use*, its main value depending upon that quality; 2, that *its effect is to produce exuberant growth;* and 3, that *it will continue to do so as long as the temperature and light required for its action are sufficient.* These three propositions, rightly understood, point to the true principles of applying it; and, if they are kept in view, no mistakes can well be made. They render it evident that the period in the growth of a plant, at which it should be applied, depends entirely upon the nature of the plant, and the object to be gained.

If, for example, wood and leaves are all that the cultivator desires to obtain, it will be evident that liquid manure may be used freely from the time when buds first break, until it is necessary that the process of ripening the wood shall begin. Wood cannot ripen so long as it is growing; wood will continue to grow as long as leaves form, and its rate of growth will be in direct proportion to their rate of development; therefore, in order to ripen wood, growth must be arrested. But the growth of wood will not be arrested so long as liquid manure continues to be applied, except in the presence of a temperature low

enough to injure or destroy it. Hence it is obvious that liquid manure must be withheld from plants grown for their wood and leaves, at the latest, by the time when two-thirds of the season shall have elapsed. To administer it in such cases towards the end of the year would be to produce upon it an effect similar to that caused by a warm wet autumn, when even hardy trees are damaged by the earliest frost.

In the case of flowers it is to be remembered that the more leaves a plant forms the fewer blossoms in *that season;* although perhaps the more in a succeeding season, provided exuberance is then arrested. The application of liquid manure is therefore unfavourable to the *immediate* production of flowers. It is further to be remarked, that even although flowers shall have arrived at a rudimentary state at a time when this fluid is applied, and that therefore their number cannot be diminished, yet that the effect of exuberance is notoriously to cause deformity; petals become distorted, the coloured parts become green, and leaves take the place of the floral organs, as we so often see with Roses grown with strong rank manure. In improving the quality of flowers liquid manure is therefore a dangerous ingredient; nevertheless its action is most important, if it is rightly given. The true period of applying it, with a view to heighten the beauty of flowers, is undoubtedly when their buds are large enough to show that the elementary organisation is completed, and therefore beyond the reach of derangement. If the floral apparatus has once taken upon itself the natural condition, no exuberance will afterwards affect it; the parts which are small will simply grow larger, and acquire brighter colours; for those changes in flowers which cause monstrous development, appear to take effect only when the organs are in a nascent state—at the very moment of their birth. Hence it is clear, that in order to affect flowers advantageously by liquid manure, it should be given to plants at the time when the flower-bud is formed and just about to swell more rapidly.

With fruit it is otherwise; the period of application should there be when the fruit, not the flowers, is beginning to swell. Nothing is gained by influencing the size or colour of the flower of a fruit-tree; what we want is to increase the size or the abundance of the fruit. If liquid manure is applied to a plant when the flowers are growing, the vigour which it communicates to them must also be communicated to the leaves; but when leaves are growing unusually fast, there is sometimes a danger that they may rob the branches of the sap required for the nutrition of the fruit; and if that happens, the latter falls off. Here, then, is a source of danger which must not be lost sight of. No doubt, the proper time for using liquid manure is when the fruit is beginning to swell, and has acquired, by means of its own green surface, a power of suction capable of opposing that of the leaves. At that time, liquid manure may be applied freely, and continued, from

time to time, as long as the fruit is growing. But, at the first sign of ripening, or even earlier, it should be wholly withheld. The ripening process consists in certain changes which the constituents of the fruit and surrounding leaves undergo; it is a new elaboration, which can only be interfered with by the continual introduction of crude matters, such as liquid manure will supply. We all know that when ripening has once begun, even water spoils the quality of fruit, although it augments the size; as is sufficiently shown by the Strawberries prepared for the London market, by daily irrigation. Great additional size is obtained, but it is at the expense of flavour; and any injury which mere water may produce, will certainly not be diminished by water holding ammoniacal and saline substances in solution.

Root-crops stand in a different position to any of the foregoing. They are most analogous to the first of the above cases; for their roots may be compared to wood, of which they are equivalents. But there is this important difference, that whereas the quantity of wood is in direct proportion to the quantity of leaves, the reverse is the case with root-crops. The Turnip that throws up an enormous tuft of leaves has a very small bulb; and so of the Carrot. In these plants the root is formed by the leaves; but only when they themselves cease growing vigorously. The true object is to obtain plenty of foliage early enough to afford time for the after formation of the root. This is what happens under ordinary circumstances. The leaves grow rapidly during the warm weather of early autumn; but when the temperature falls, their own development is languid, and all their energy is expended in augmenting the mass below them. By the constant application of liquid manure a Turnip might be absolutely prevented from forming more root than a Cabbage. In root-crops what is wanted is an abundant supply of liquid manure when the leaves are forming, so as to secure early a large and vigorous foliage; after which no liquid manure whatever ought to be applied. This is quite consistent with the evidence collected by Mr. Dudley Fortescue, and published in the Minutes of the Board of Health. Speaking of Mr. Kennedy's farm in Ayrshire, this gentleman says: "Of the Turnips, one lot of Swedes dressed with ten tons of solid farm manure, and about 2000 gallons of the liquid, having six bushels of dissolved bones along with it, *was ready for hoeing ten or twelve days earlier* than another lot dressed with double the amount of solid manure without the liquid application and were fully equal to those in a neighbour's field which had received thirty loads of farm-yard dung, together with three cwt. of guano and sixteen bushels of bones per acre; the yield was estimated at forty tons the Scotch acre, and their great luxuriance seemed to me to justify the expectation. From one field of White Globe Turnips sown later, and *manured solely with liquid*, from forty to fifty tons to the Scotch acre was expected. A field of Carrots treated in the same manner as th

Swedes, to which a second application of liquid was given *just before thinning*, promises from twenty to twenty-five tons the acre."

There is a mode of applying liquid manure, not by superficial channels, but by underground pipes, filled from a head, which would force the manure upwards into the soil by virtue of its own pressure. There is no doubt that this plan, which was, I believe, first proposed by the Right Hon. T. F. Kennedy, lately one of H.M.'s Commissioners of Woods, &c., is theoretically the best. The sole objection to it is the cost of its application. The Dutch do nearly the same thing by a method mentioned below, and it may be conceived that a combination of the two methods would be preferable to either.

Mr. Prideaux remarks that "the Dutch, who are admirable gardeners, had in the Great Exhibition an instrument called 'Earth-borer,' for manuring fruit-trees without digging the ground. A circle of holes is bored round the tree, at two feet distance from the tree, and a foot from each other. Taking the tree at a foot diameter at the surface of the soil, the circle will be five feet diameter and fifteen feet circumference; and if the holes are three inches diameter and a foot apart = fifteen inches, there will be about twelve holes; more or less according to the diameter of the tree. They are eighteen inches deep (where there is enough depth of soil), and slanting towards the centre; are filled with liquid manure, diluted more or less in dry weather, and stronger as the weather is wetter."

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